ASML's NXE platform performance

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EUVL

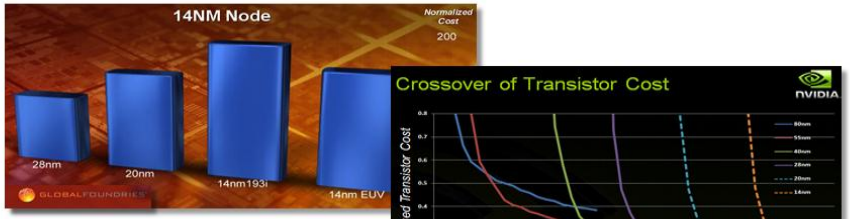
Toyama

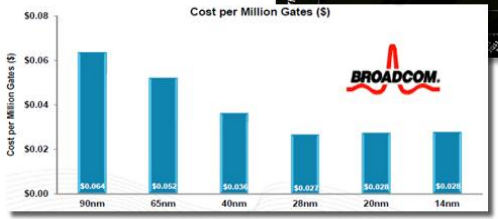
Oct 7, 2013

Contents

EUV is a cost effective solution

Cost scaling becomes greater concern with shrinks below 28nm





Sources: nVidia, ITPC, Nov, 2011
Broadcom, IMEC, may 2012
GF, ISS, Jan 2013

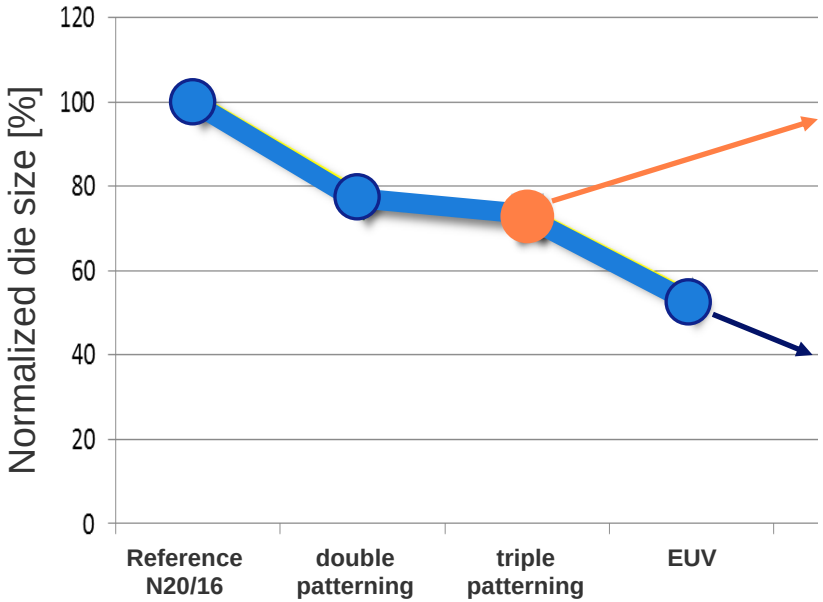
EUV single exposure reduces Cost and Cycle Time vs. Multiple Patterning

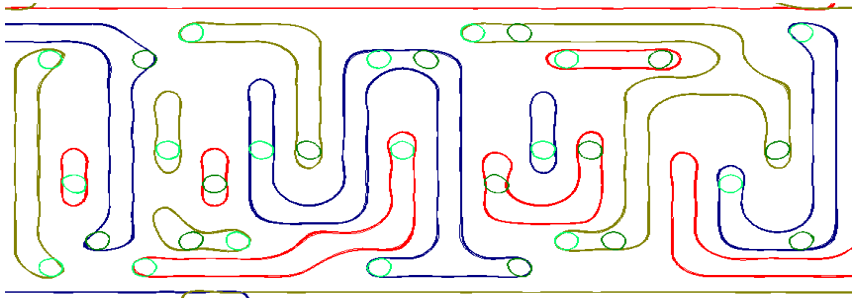
Relative to EUV	LE²	SADP	SAQP
Process Steps	x2	x4	x5
Process Cost	+10%	+30~50%	+>50%
Cycle Time	x2	x4	x5

LE = Litho-Etch, n = number of iterations
SADP = Self Aligned Double Patterning
SAQP = Self Aligned Quadruple Patterning

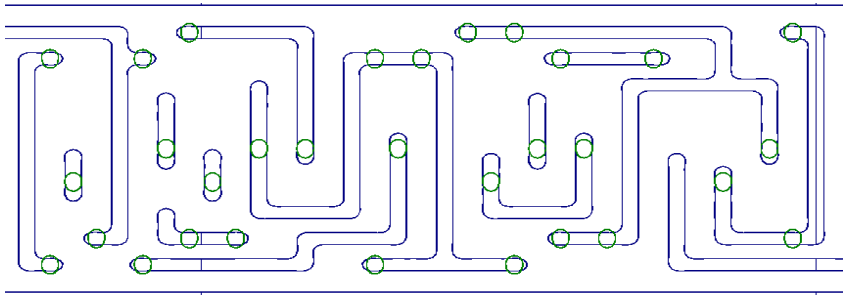
EUV enables 50% Scaling for the 10 nm logic node

Layout restrictions and litho performance limit shrink to ~25% using immersion





Triple patterning does not show a process window



EUV meets all litho requirements

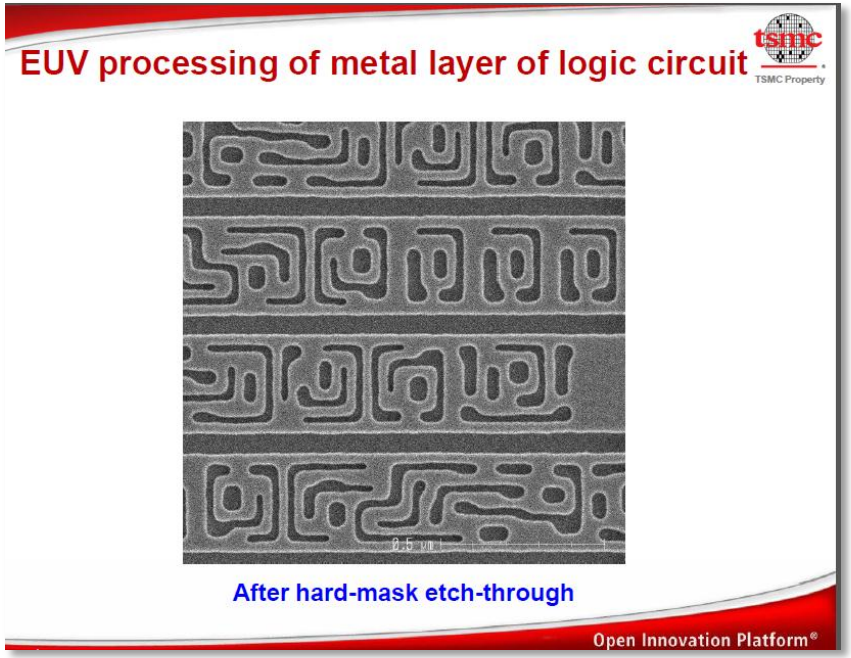
Source: ARM

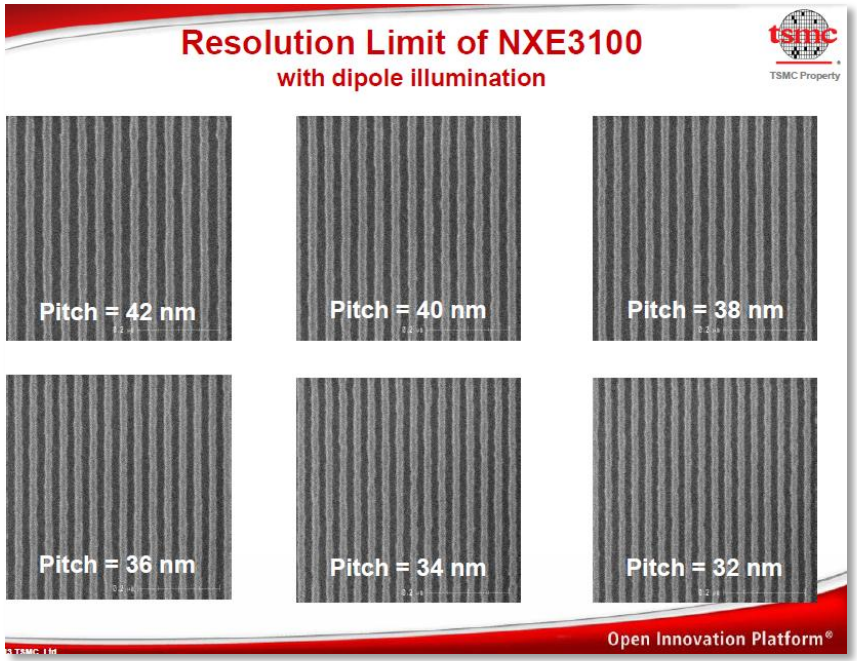
ASML's NXE:3100 and NXE:3300B

	NXE:3100	NXE:3300B
NA	0.25	0.33
Illumination	Conventional 0.8 σ	Conventional 0.9 σ Off-axis illumination
Resolution	27 nm	22 nm
Dedicated Chuck Overlay / Matched Maching Overlay	4.0 nm / 7.0 nm	3.0 nm / 5.0 nm
Productivity	6 - 60 Wafers / hour	50 - 125 Wafers / hour
Resist Dose	10 mJ / cm2	15 mJ / cm2

Contents

NXE:3100 in use at customers for cycles of learning



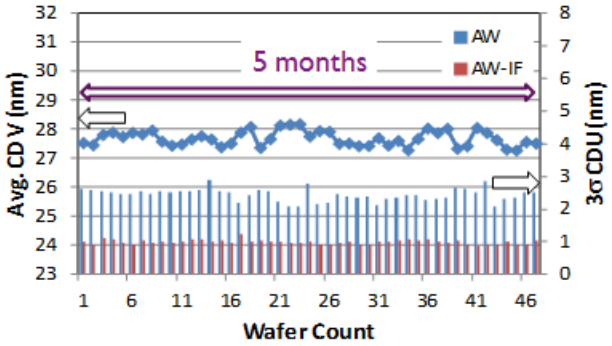


Data courtesy of TSMC

NXE:3100 shows stable performance

LONG TERM WAFER STABILITY OF 27nm V LS - NOV'12-APR'13, CONV.ILL. 14MJ/CM2, YIELDSTAR S200

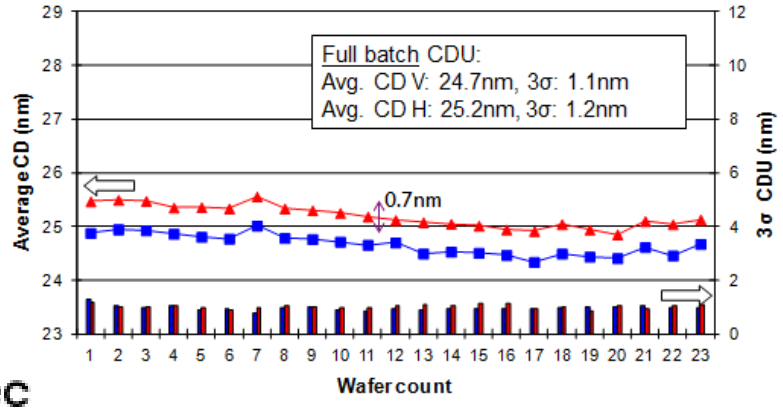
71 fields/wafer, 26x33mm², 5x3 intrafield sampling



imec

FULL BATCH CD UNIFORMITY OF 27nm LS

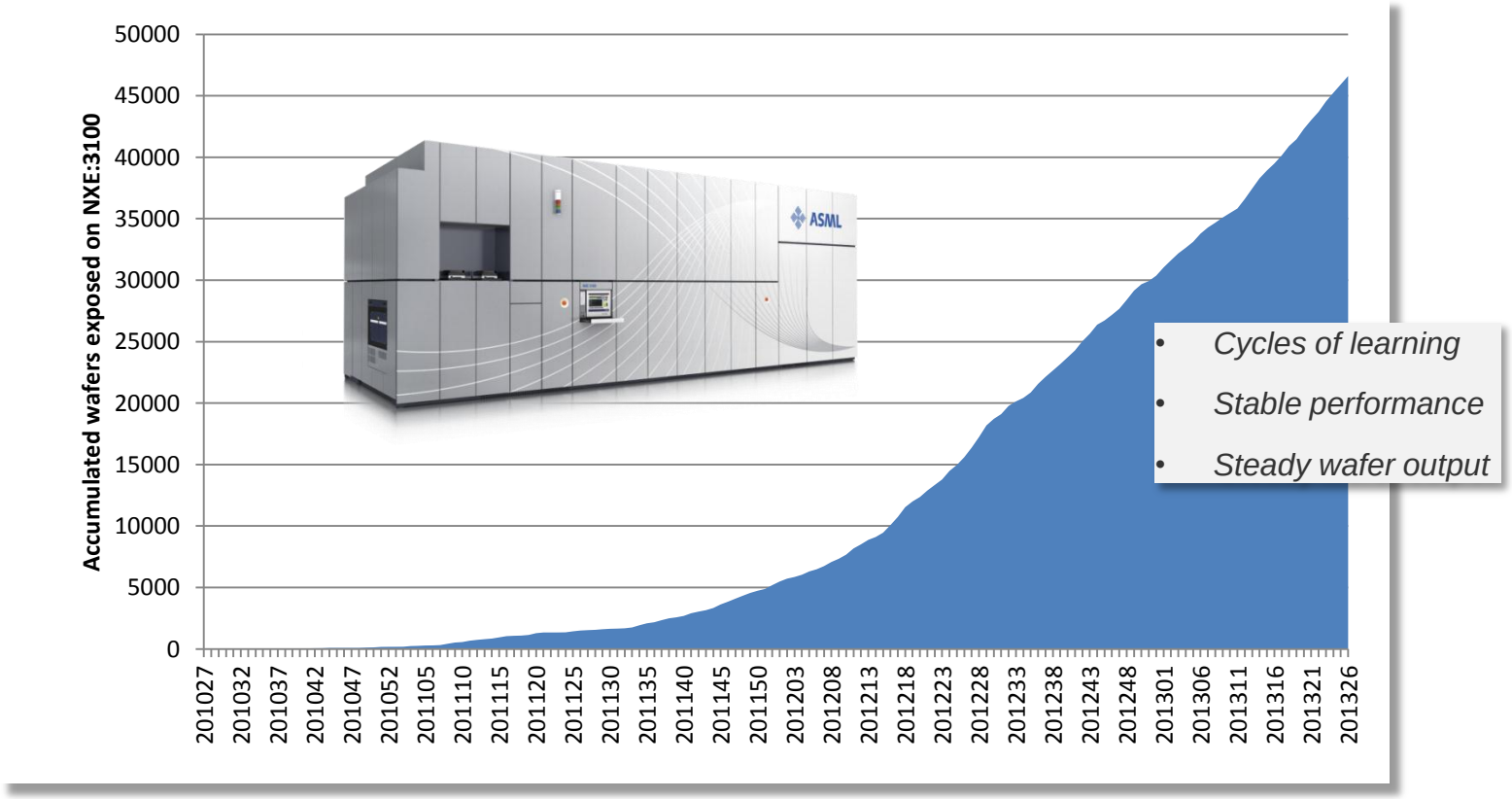
23 wafers, 83 fields/wafer, 1 point/field, Hitachi CG-4000



imec

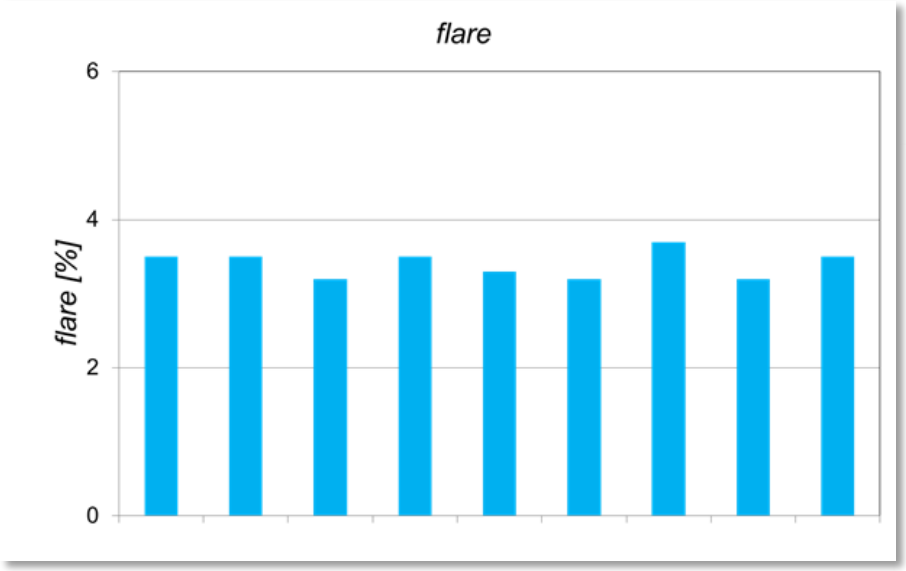
Data courtesy of imec

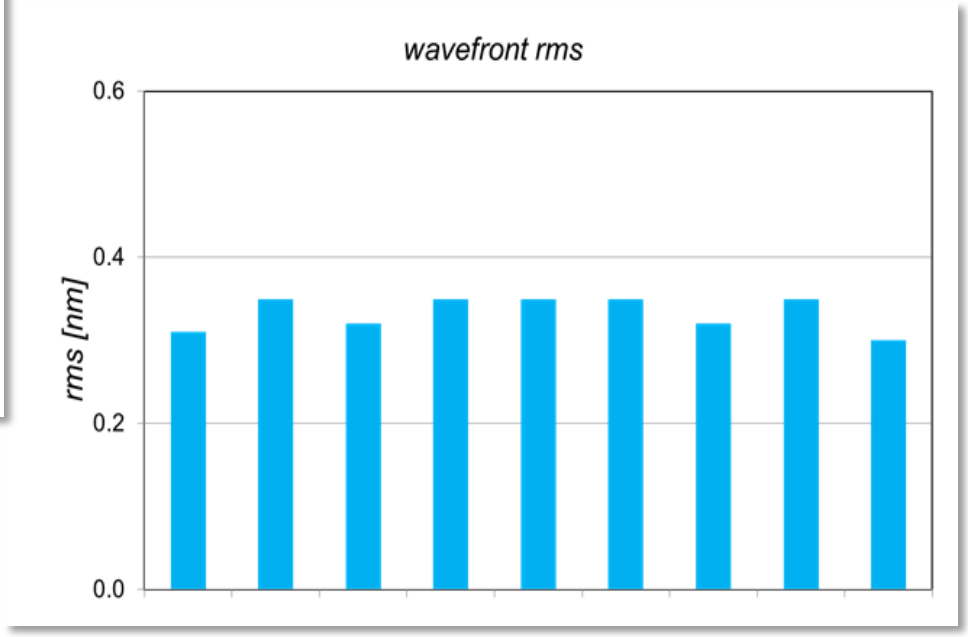
The NXE:3100 has exposed >46,000 wafers



Contents

Lens performance consistent and better than requirements *population for NXE:3300B*



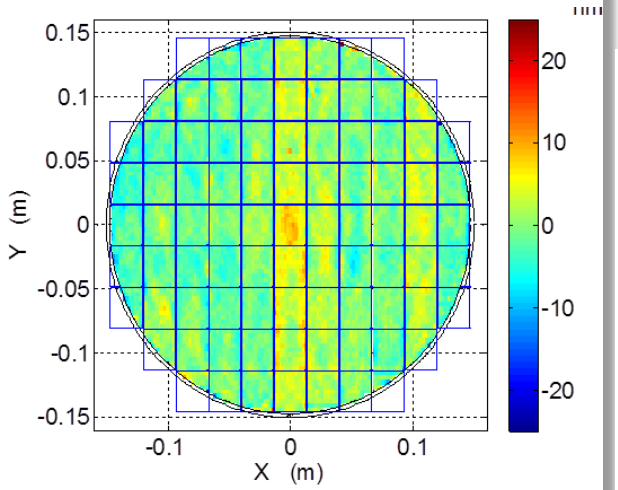


Every bar is an individual lens

Data courtesy of Carl Zeiss SMT GmbH

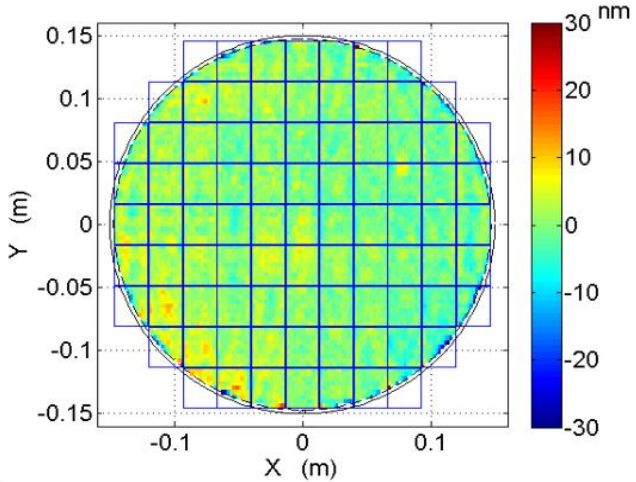
NXE:3300B shows excellent focus performance

Focus uniformity performance across the wafer <12nm



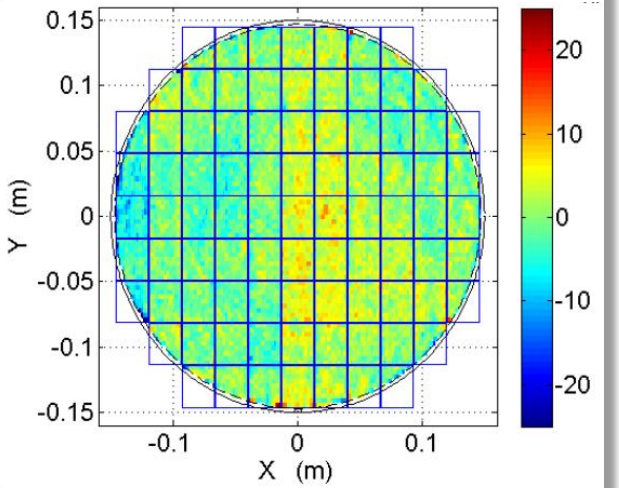
System A

10.4nm



System B

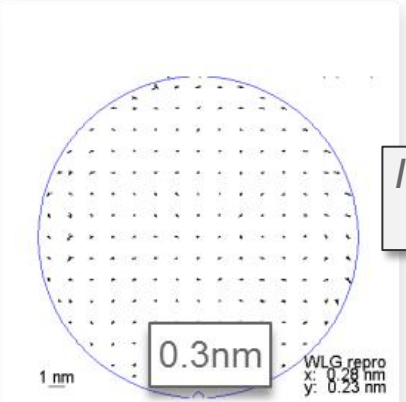
9.5nm



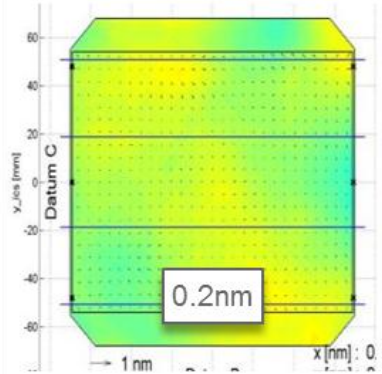
System C

11.5nm

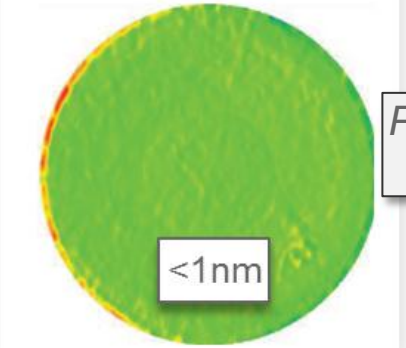
Module improvements to support better overlay on the NXE:3300B system



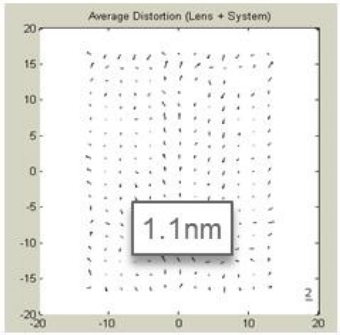
Improved wafer load grid performance



Flatter reticle stage clamps

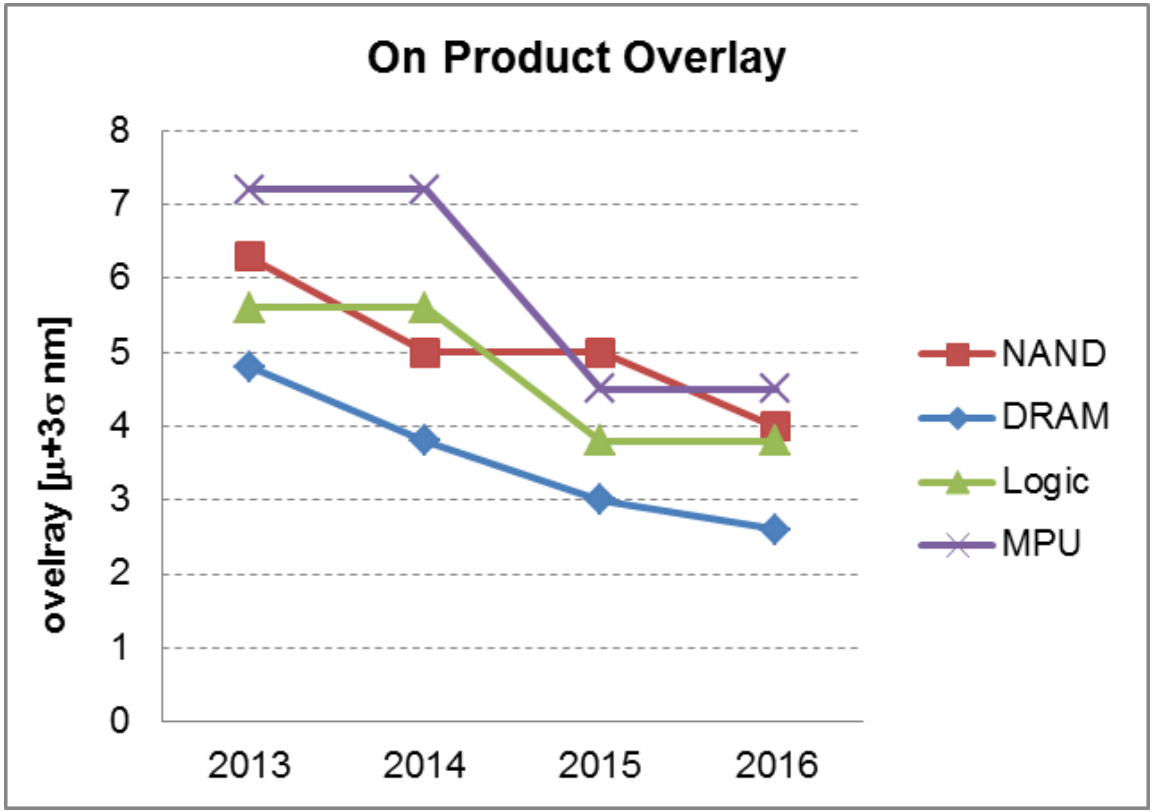


Flatter wafer clamp flatness



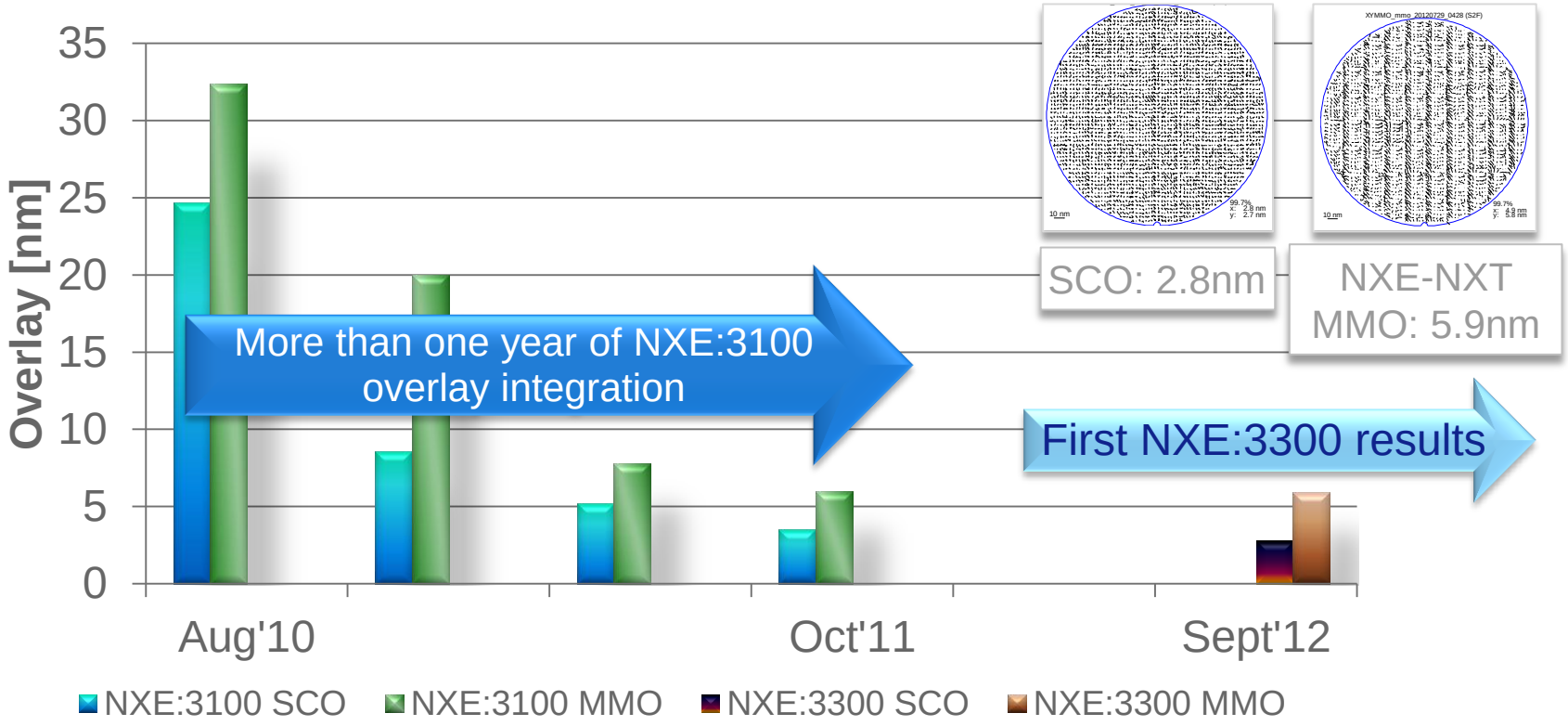
Improved lens performance

Customer On-Product-Overlay roadmap

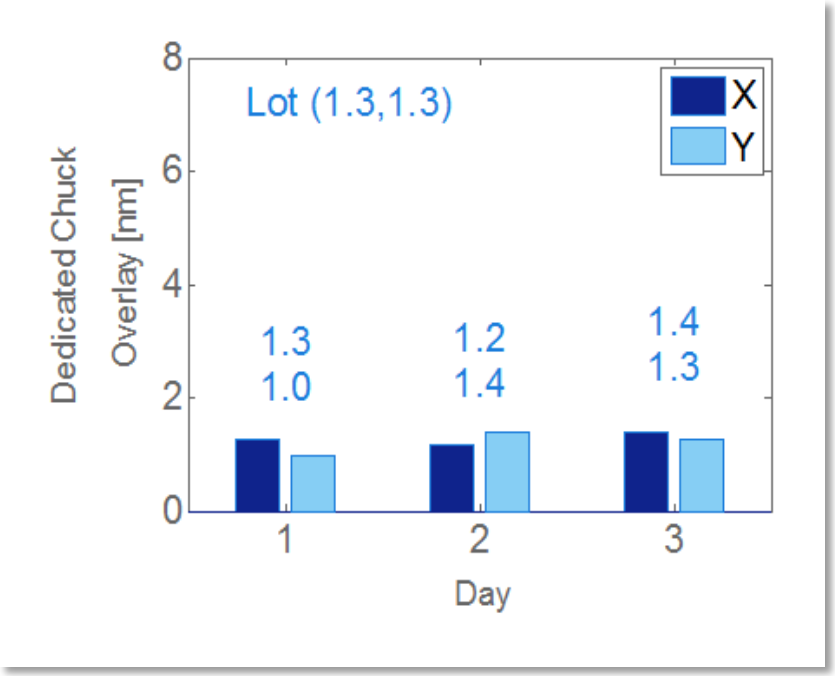


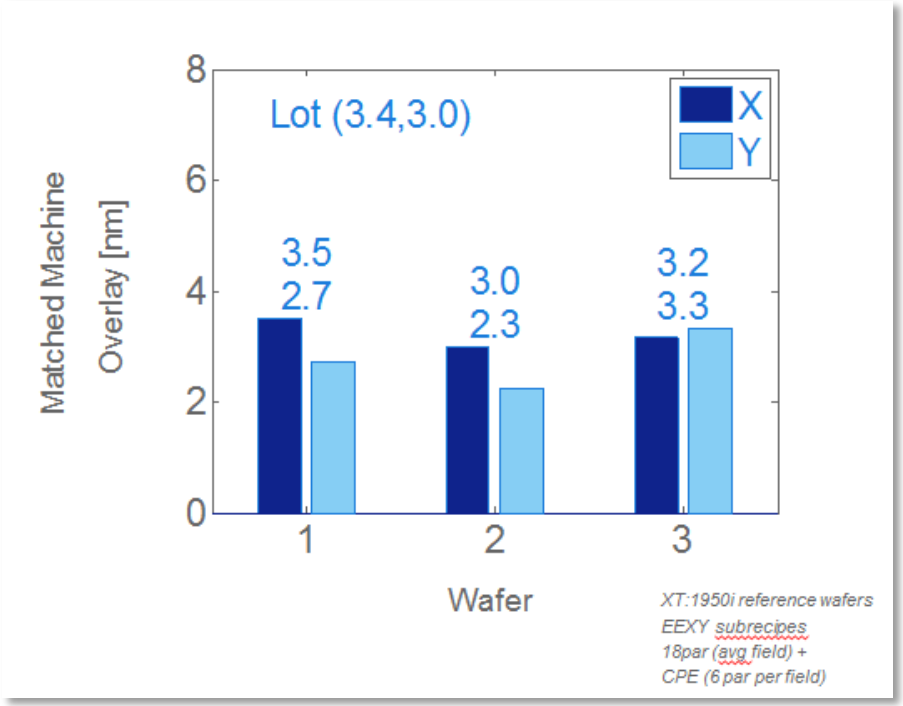
ASML assessment based on customer inputs

NXE overlay performance presented at EUVL 2012

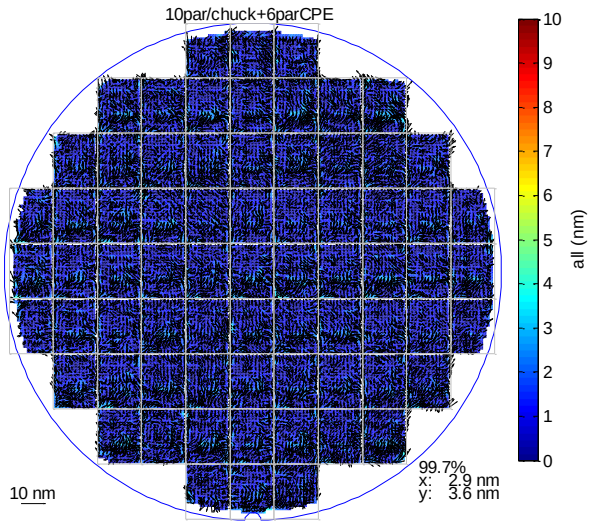


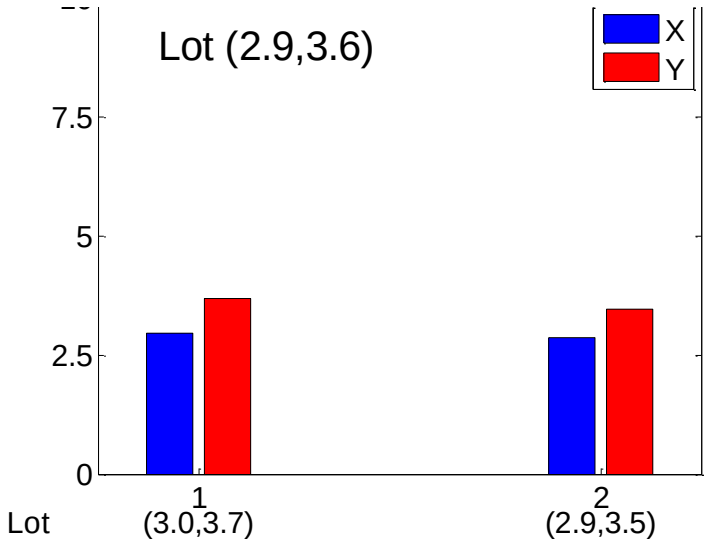
NXE:3300B overlay performance improved significantly within one year





NXE:3300B matched machine overlay to NXT:1970Ci <3.6nm





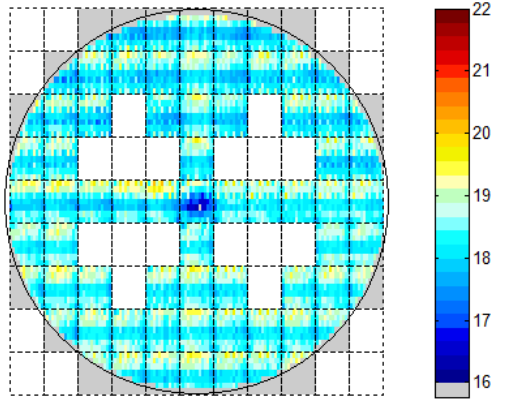
10par/chuck+6par CPE corrected

6parCPE modeled from average wafer

Full wafer CDU performance for 22nm dense and iso lines at required performance level

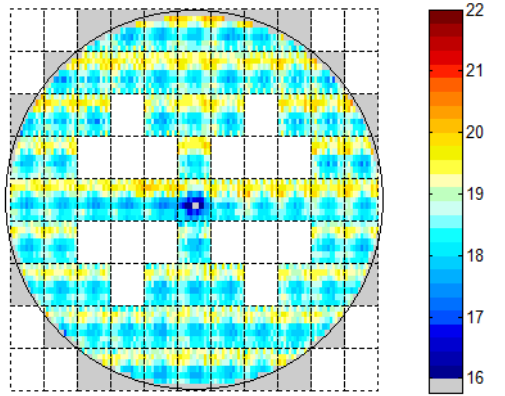
Dense lines H

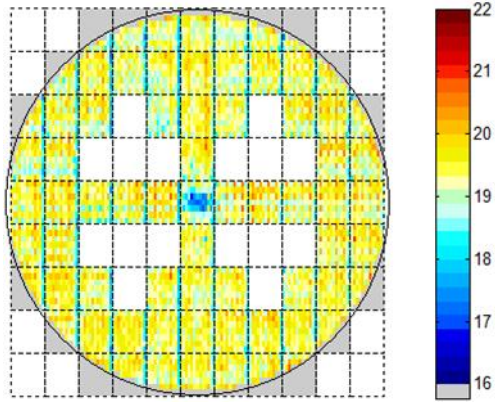
FWCDU = 1.5nm



Dense lines V

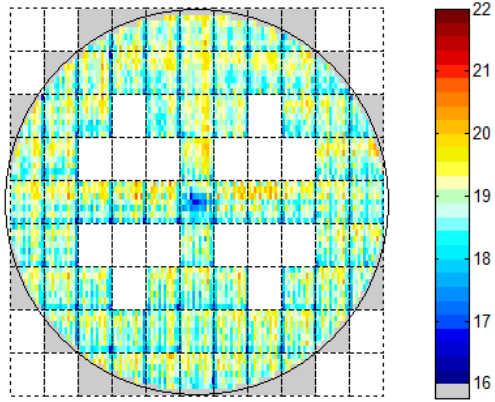
FWCDU = 1.4nm





Isolated lines H

FWCDU = 1.6nm

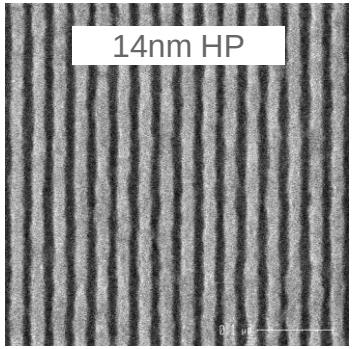


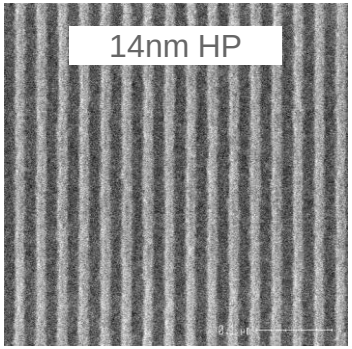
Isolated lines V

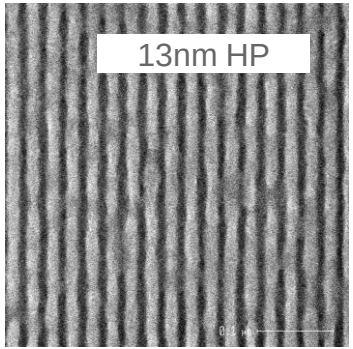
FWCDU = 1.7nm

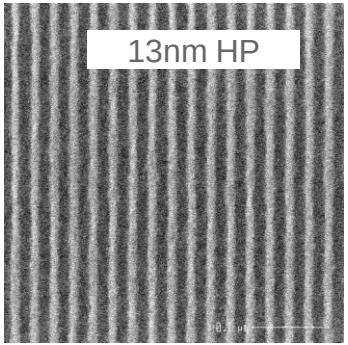
Measured with Yieldstar, targeted with SEM

Resolution shown on NXE:3300B for dense line spaces, regular and staggered contact holes; all single exposures







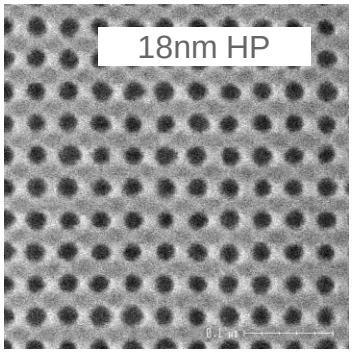


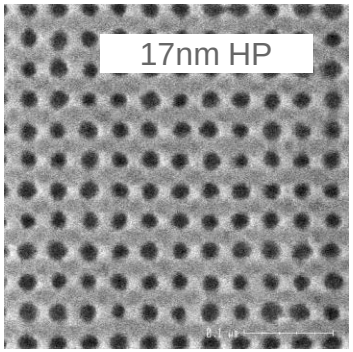
Dipole30,

Chemically Amplified Resist (CAR)

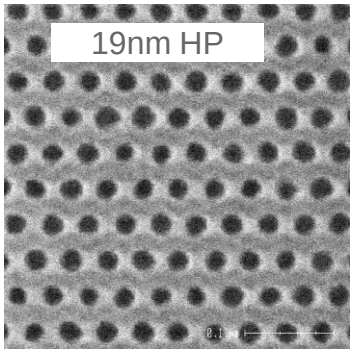
Dipole45,

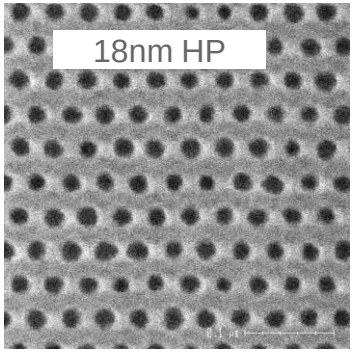
Inpria Resist





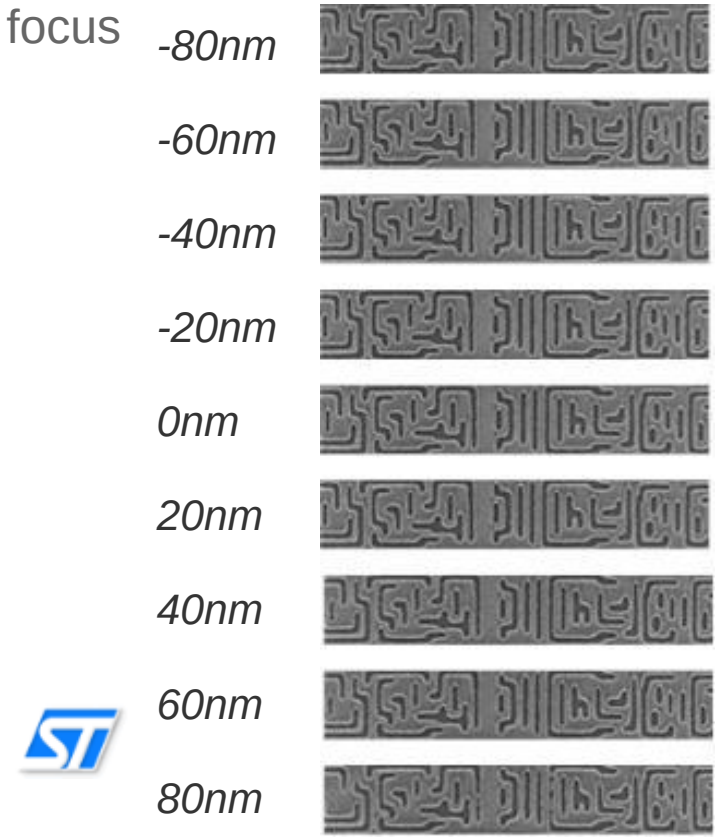
Quasar 30 (CAR)





Large Annular (CAR)

NXE:3300B enables single exposure random logic metal layer with large DoF *minimum HP 23 nm (N10 logic cell)*

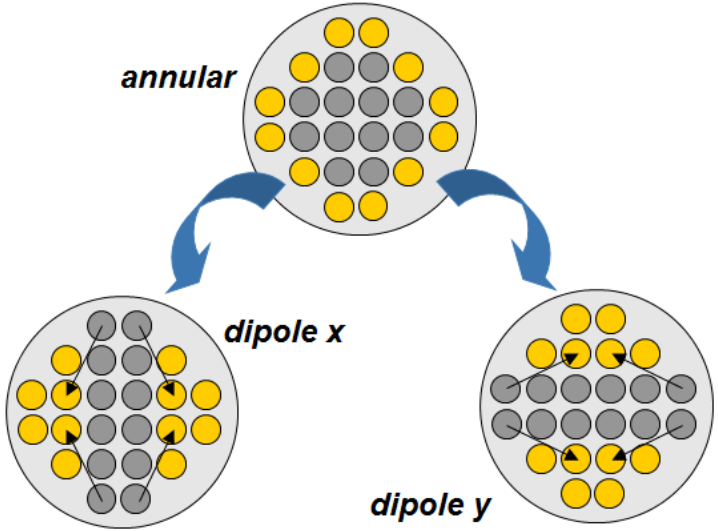


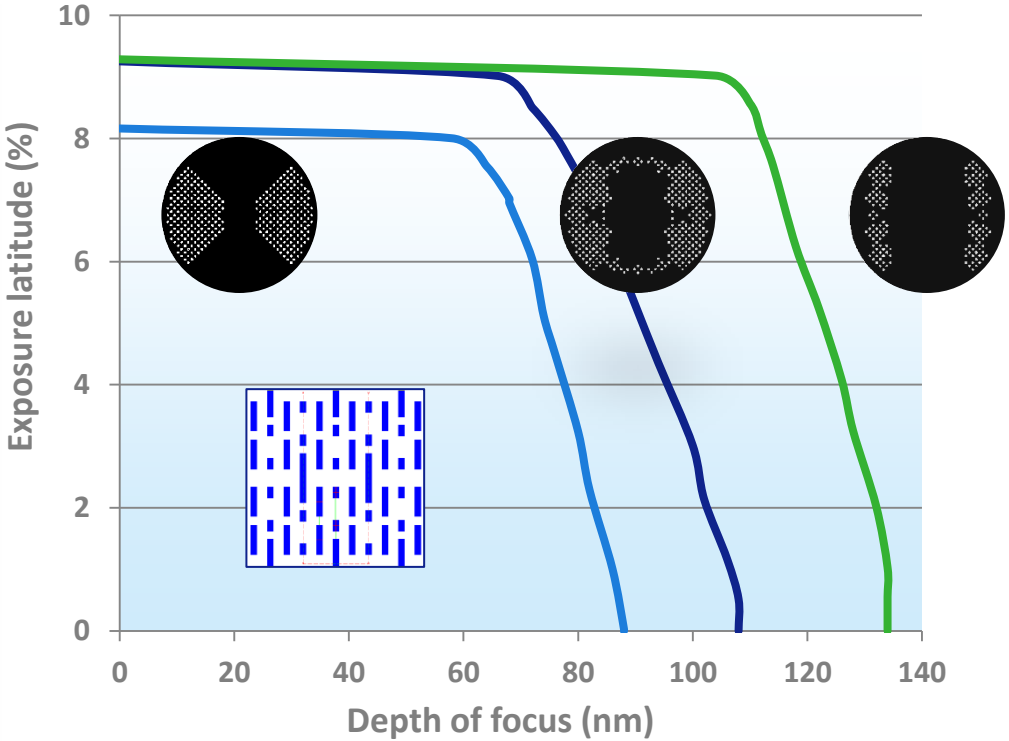
EUV	ArF immersion
▪ Node: N10 (23nm HP) ▪ **Target insertion point for EUV**	▪ Node: N20 (32nm HP)
▪ Single Exposure ▪ Conventional illumination	▪ Double Patterning (design split)
▪ Best focus difference ~10nm	▪ Best focus difference up to 40-60nm
▪ Overlapping DoF current 100..120nm *(expected to improve after further optimization (e.g. OPC))*	▪ Overlapping DoF typical ≈ 60nm

Position in the exposure slit

Excellent print performance over the full exposure slit

The NXE:3300B offers new concept off-axis illumination to enhance process window

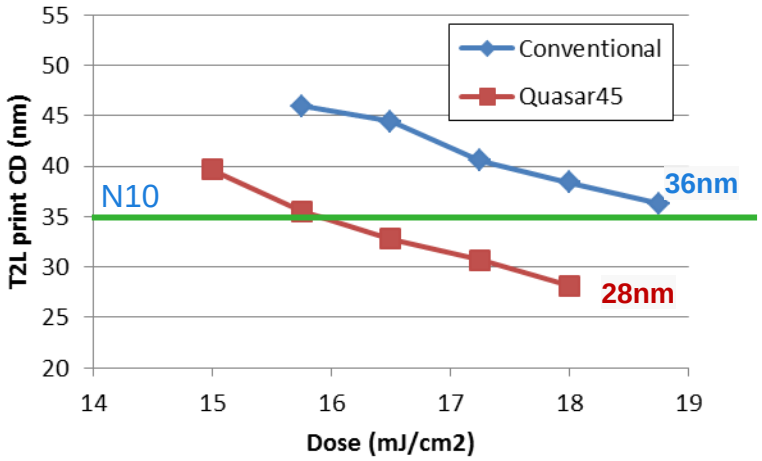




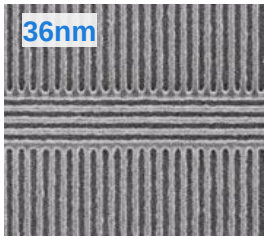
Simulations by Tachyon SMO NXE

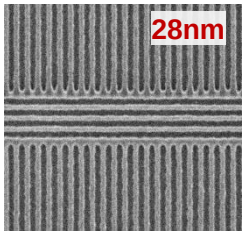
Line ends - tip2line minimum print gap size at a dose of <16mJ/cm2 with off-axis illumination

Lower dose resist



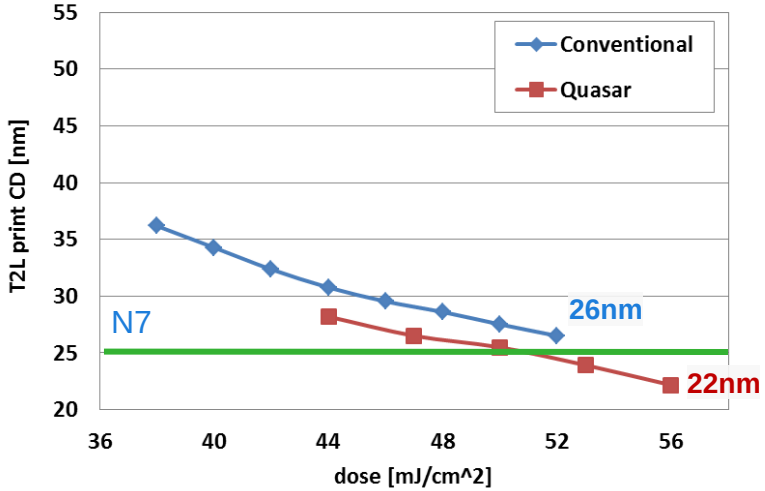
Conv.





Quasar

Higher dose resist



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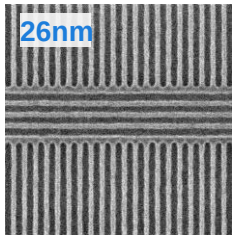
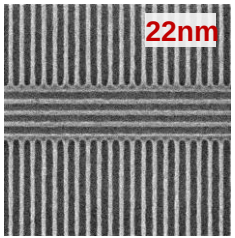


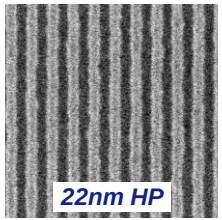


Quasar

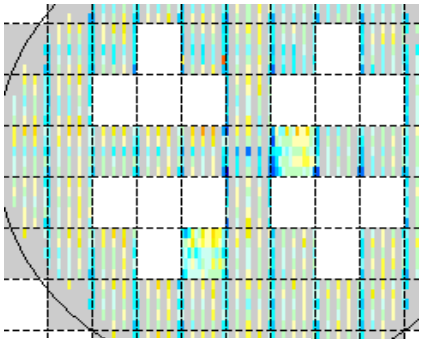
NXE:3300B imaging and overlay beyond expectations

matched overlay to immersion ~3.5nm

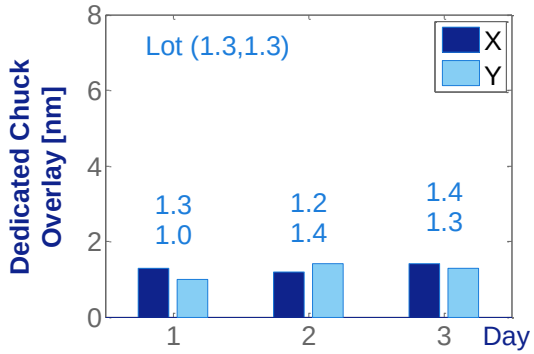
Scanner qualification

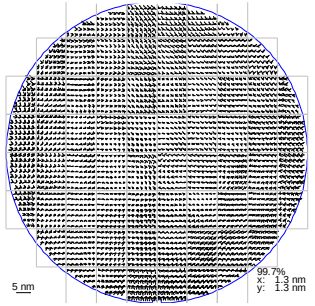


BE = 15.9 mJ/cm²
EL = 13%
DoF = 160 nm

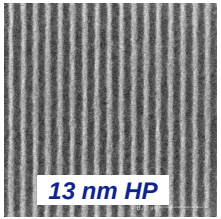


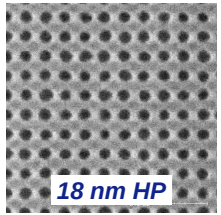
Full wafer CDU = 1.5nm

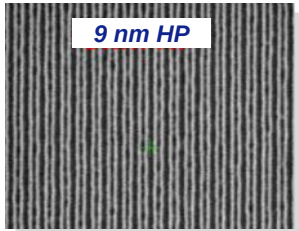




Scanner capability

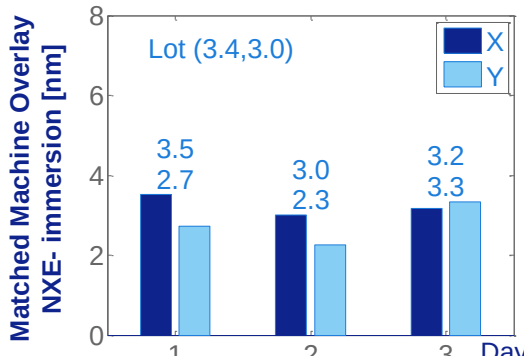


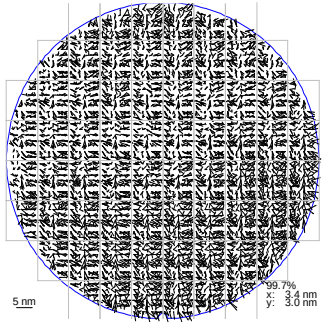




Single exposure

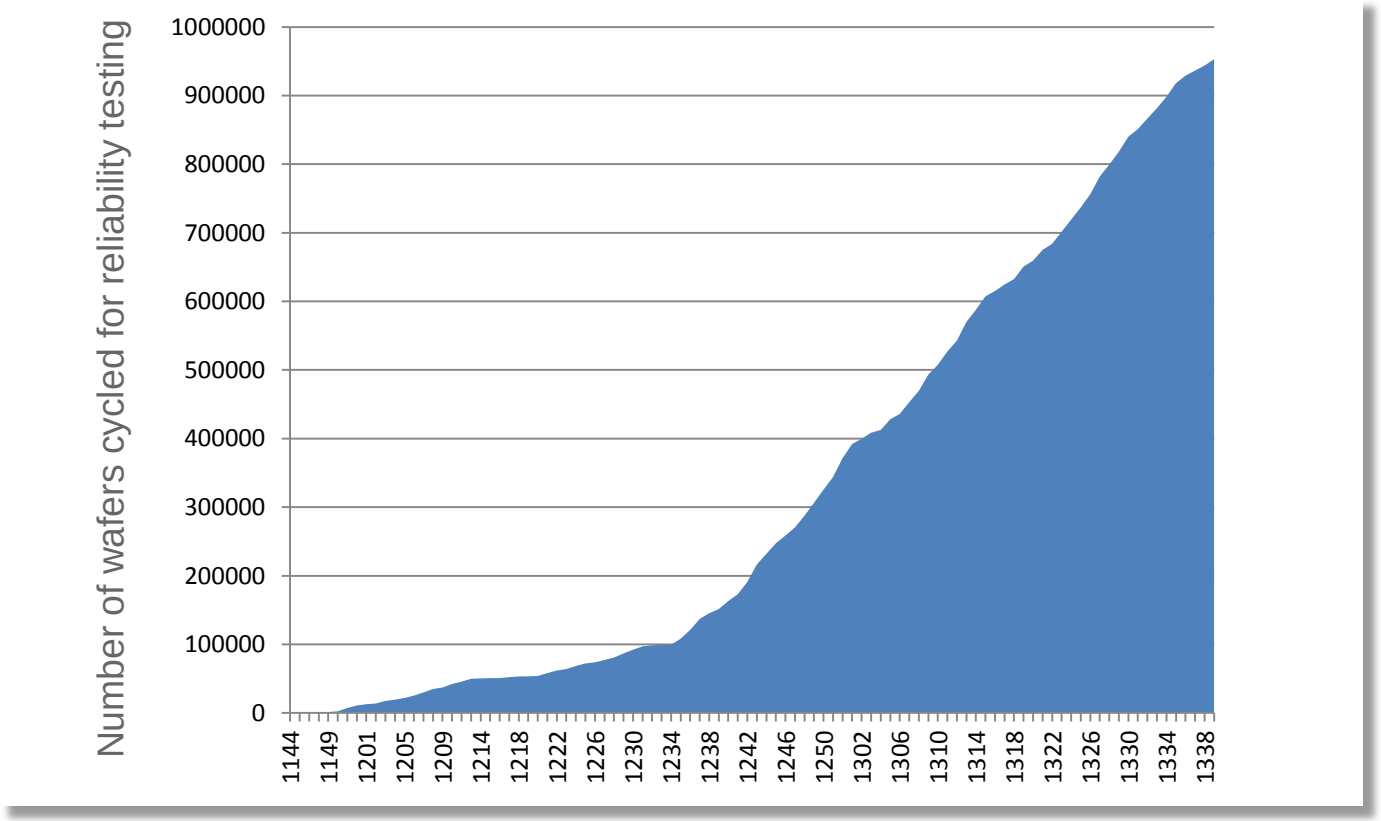
EUV Spacer



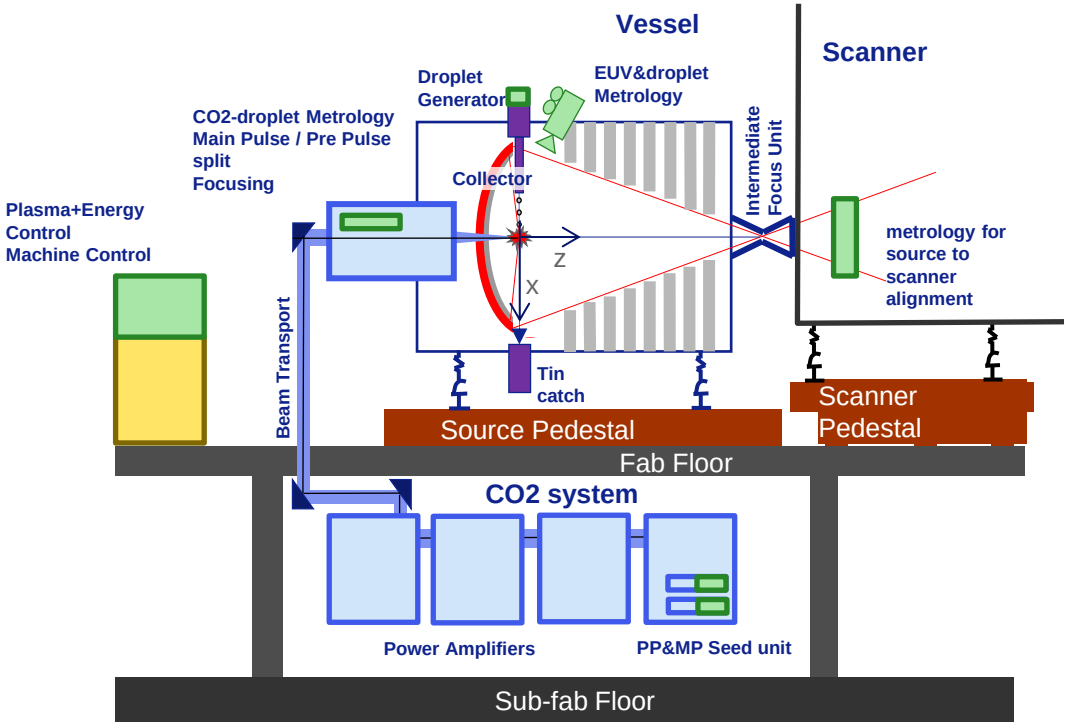


XT:1950i reference wafers
EEXY sub-recipes
18par (avg. field) +
CPE (6 par per field)

>900,000 wafer cycled on NXE:3300B for integration and reliability testing



EUV source system cross-section



x=droplet stream direction, z=CO2 light direction, y=orthogonal

Key components:

- Drive Laser
- Collector

→ **Power**

- Droplet generator
- Vessel

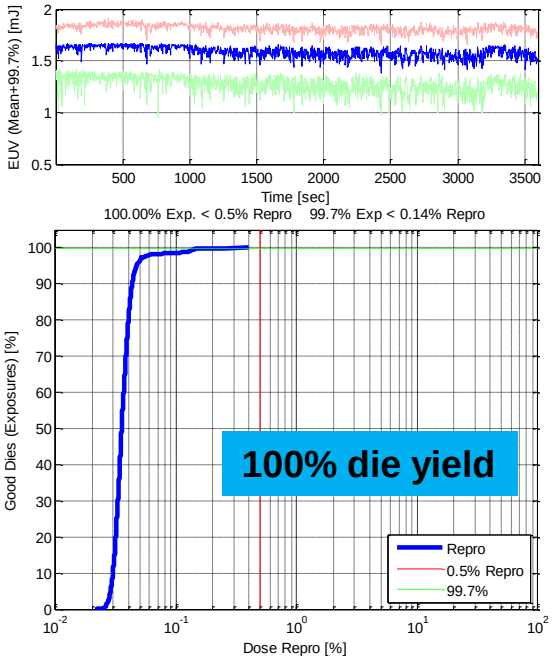
→ **Availability**

- Controls (E,x,y,z,t)
- Final Focus Assembly

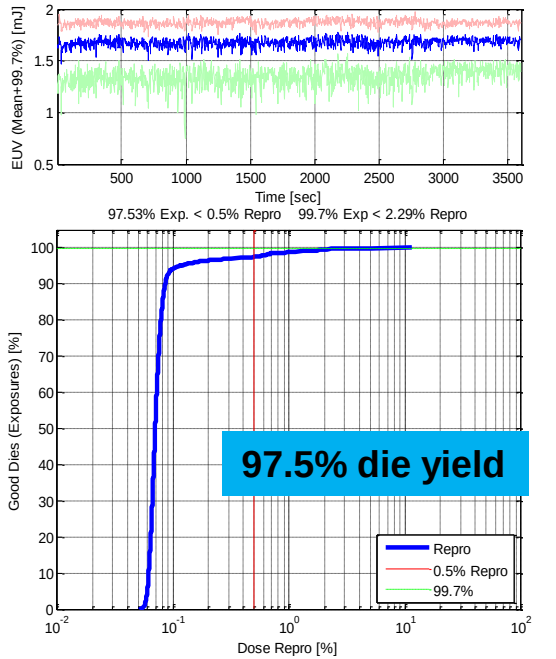
→ **Dose control**

MOPA-PrePulse EUV power demonstrated up to 55W under closed loop dose control

50W

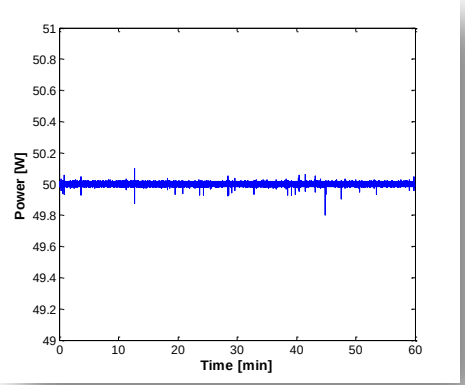


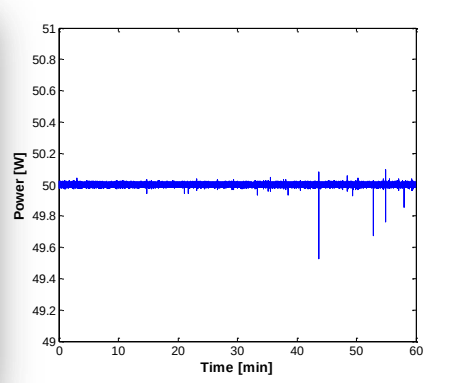
55W

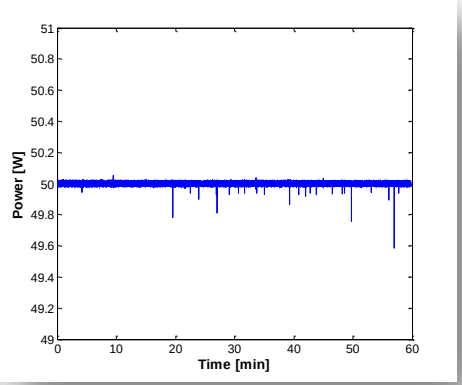


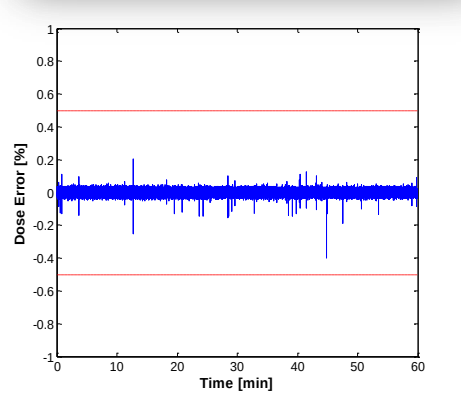
Repeatable 50W MOPA PrePulse EUV Power and Dose Stability

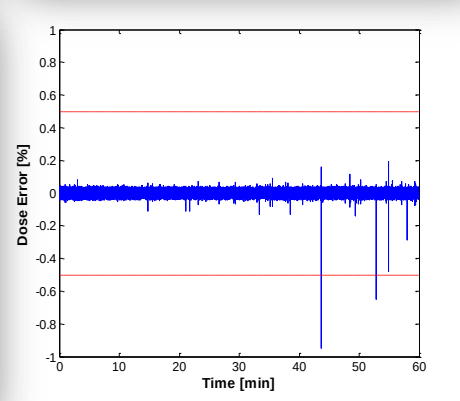
Dose Stability <±0.5%, Die Yield >99.7%

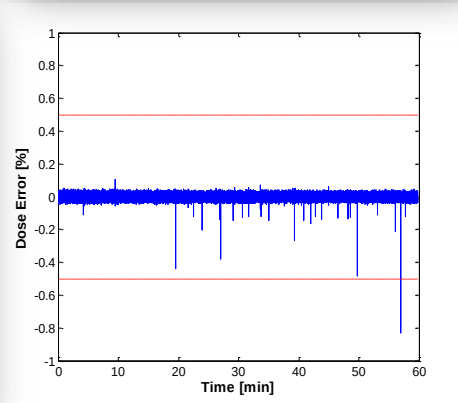






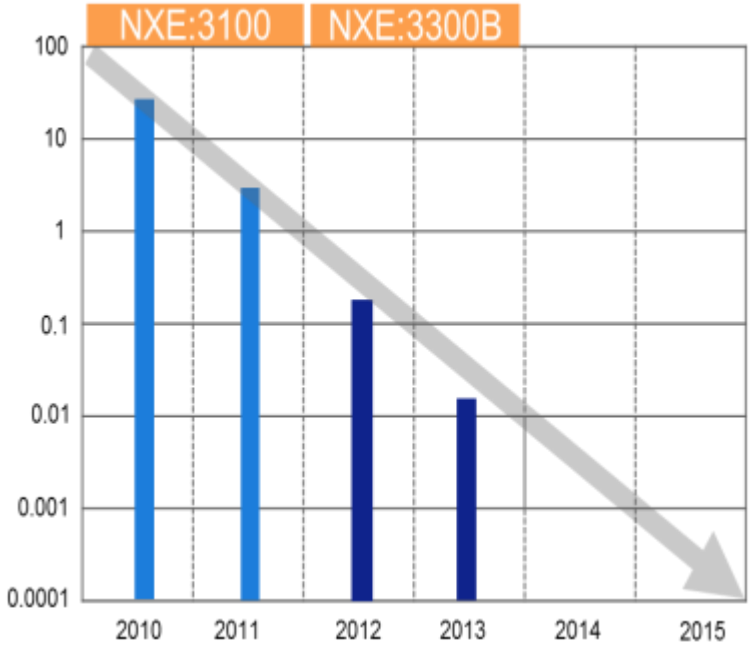






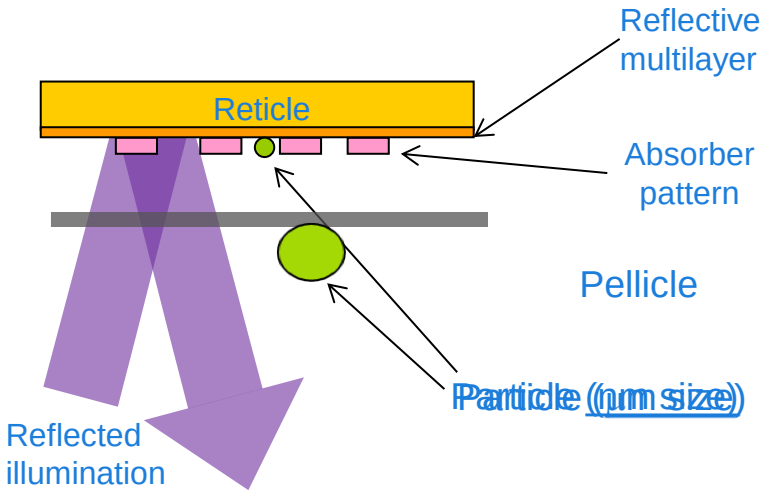
The mask defect challenge

ASML achieved 10x per year improvement for pellicle-less operation (pellicle would reduce defect requirements substantially)



Progress made on ASML machines on added particles per reticle exchange over the past few years

EUV Reticles (13.5nm)

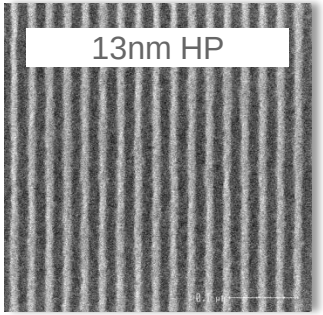


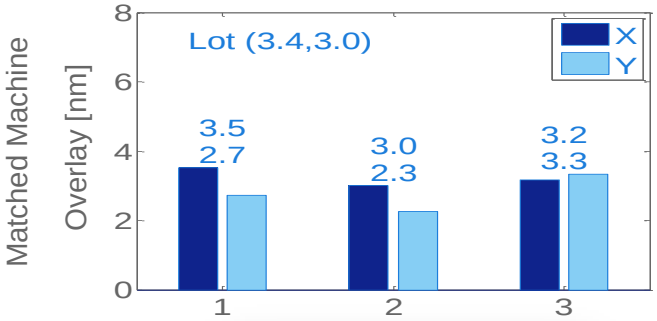
Customer requirement for full production without pellicle @ resolution

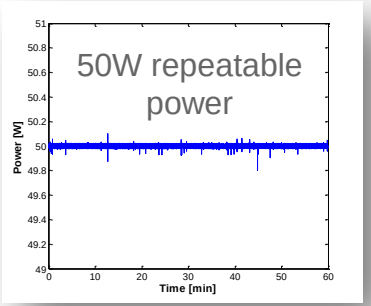
Contents

Summary

- **NXE:3100** in use for process and device development at customers
- **NXE:3300B** performance fit for customer development 10nm Logic and sub-20nm DRAM
  - Overlay performance of DCO<2nm and MMO<4nm demonstrated
  - Resolution of 13nm LS and 18nm Contact Holes demonstrated. Further process optimization to be done
  - Good imaging performance for 1D (Line Space), 2D (Contact Holes and Metal 1), and Tip-to-Tip / Tip-to-Line have been shown
  - Dose reduction achieved by utilizing contrast enhancement with off-axis illumination
  - 50W repeatable source power demonstrated with good dose control
  - Good progress in defectivity performance improvements and pellicle development







Acknowledgements

The work presented today, is the result of hard work and dedication of teams at ASML and many technology partners worldwide including our customers

Special thanks to our partners and customers for allowing us to use some of their data in this presentation