Imaging performance at 22nm and beyond with the NXE:3300

Koen van Ingen Schenau

2013 EUVL Symposium, Toyama

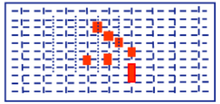
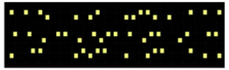
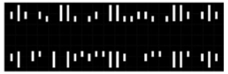
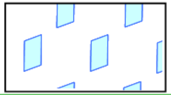
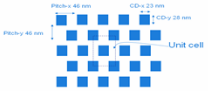
ASML's NXE:3300B

	NXE:3100	NXE:3300B
NA	0.25	0.33
Illumination	Conventional 0.8 σ	- Conventional 0.9 σ - Off-axis illumination (OAI)
Resolution	27 nm	22 nm
Dedicated Chuck Overlay / Matched Machine Overlay	4.0 nm / 7.0 nm	3.0 nm / 5.0 nm
Productivity	6 - 60 Wafers / hour	50 - 125 Wafers / hour

Contents

- Customer user cases
- Logic applications
  - 2D random logic & line ends
- DRAM applications
  - 1D line/ spaces
  - 2D contact hole arrays
- Photoresist progress
- Exposure tool outlook
- Conclusions

Customer user cases and requirements for EUV

	yr intro to HVM yr for development	2014 2013	2015 2014	2016 2015	2017 2016	target CD	CDU
Logic Cut mask		N10		N7		1*HP	
Logic Metal			HP23 N10		HP16 N7	1.3*HP	10% (1D), 15% (2D) in resist
Logic Via			N10		N7		
Local Interconnect			N10		N7		
DRAM_AA (SE-tilted grating)		HP20	HP19	HP15	HP13	1*HP	
DRAM_AA (Cut)							
DRAM_SN_Hny		HP33	HP30.5	HP24	HP21	1.1*HP	10% after etch

AA = Active Area

SN = Storage Node

HNY = Honeycomb

*ASML assessment based on customer inputs

Random logic metal layer most stringent user case

NXE:3300B enables single exposure with large DoF

ArF immersion	EUV
▪ Node: N20 (32nm HP)	▪ Node: N10 (23nm HP)
▪ Double Patterning (design split)	▪ Single Exposure ▪ Conventional illumination
▪ Best focus difference up to 40-60nm	▪ Best focus difference ~10nm
▪ Overlapping DoF typical ≈ 60nm	▪ Overlapping DoF current 100-120nm

Position in the exposure slit

-12mm ***0mm*** ***+12mm***

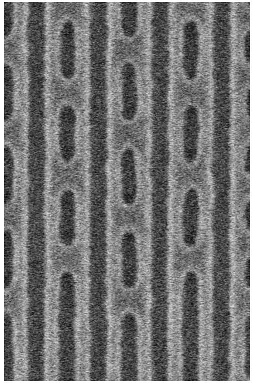
Excellent print performance over the full exposure slit

-80nm
-60nm
-40nm
-20nm
0nm
20nm
40nm
60nm
80nm

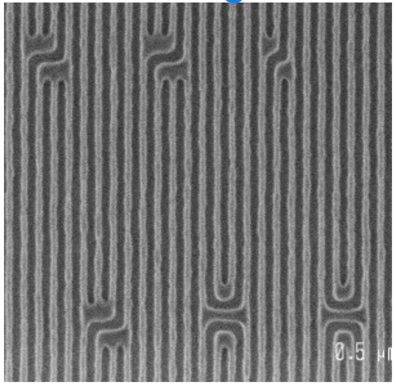
focus

Line-end performance and control relevant for many structures

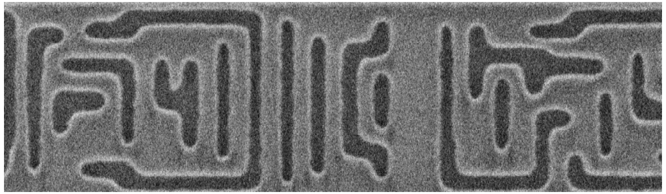
SRAM



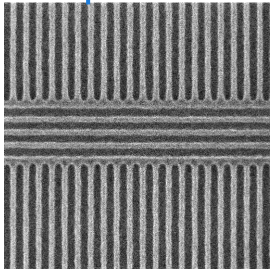
routings



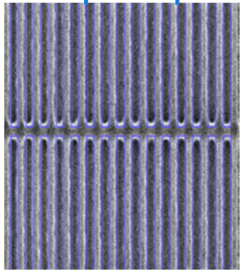
Random logic (Metal)



Tip2Line



Tip2Tip

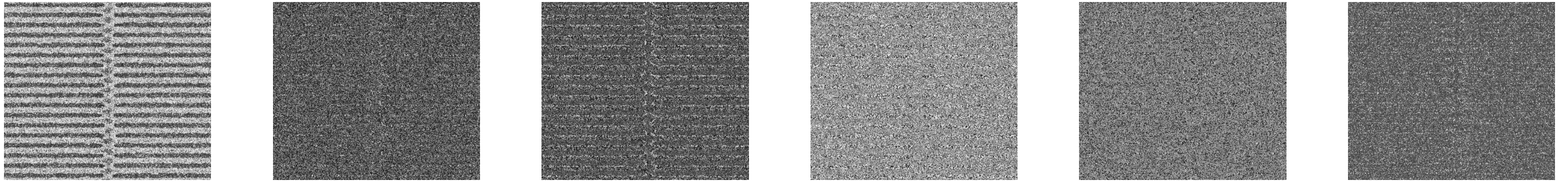


Dedicated OPC test features for performance qualification:

- Precise line end (gap) measurement
- enables accurate OPC model calibrations

NXE3300: Line ends - tip2tip minimum print gap size

tip2tip printed gap size down to 30nm with Quasar illumination

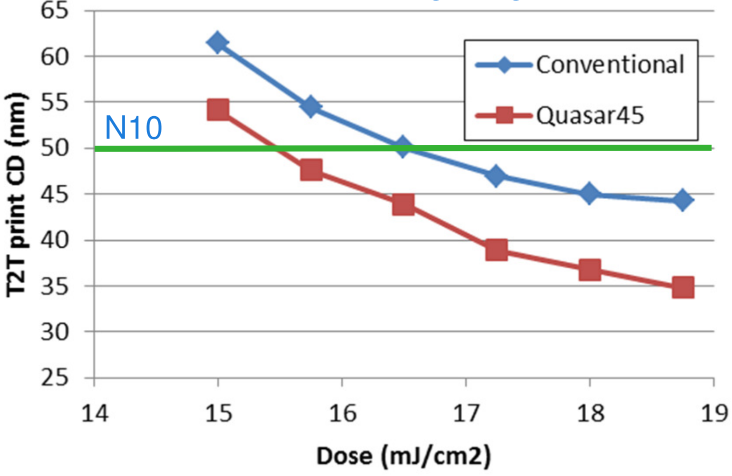


15 mJ/cm² | 15.75 mJ/cm² | 16.5 mJ/cm² | 17.25 mJ/cm² | 18 mJ/cm² | 18.75 mJ/cm²

QUASAR ILL.

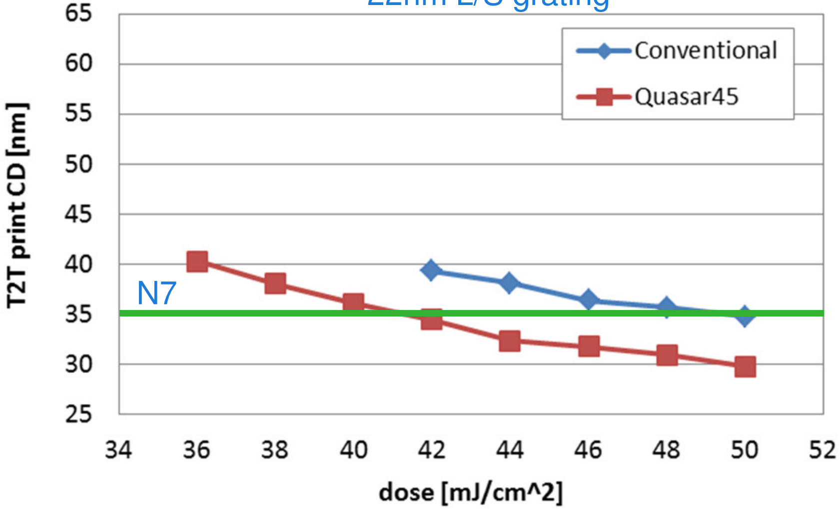
Lower dose resist, 20nm mask gap

22nm L/S grating



Higher dose resist, 20nm mask gap

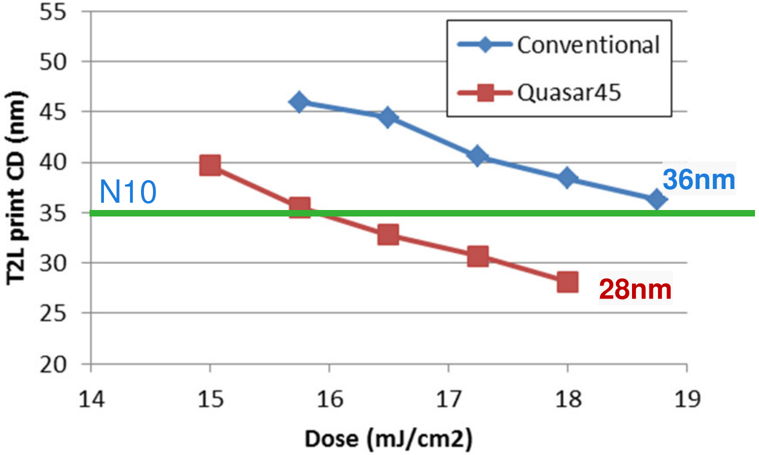
22nm L/S grating



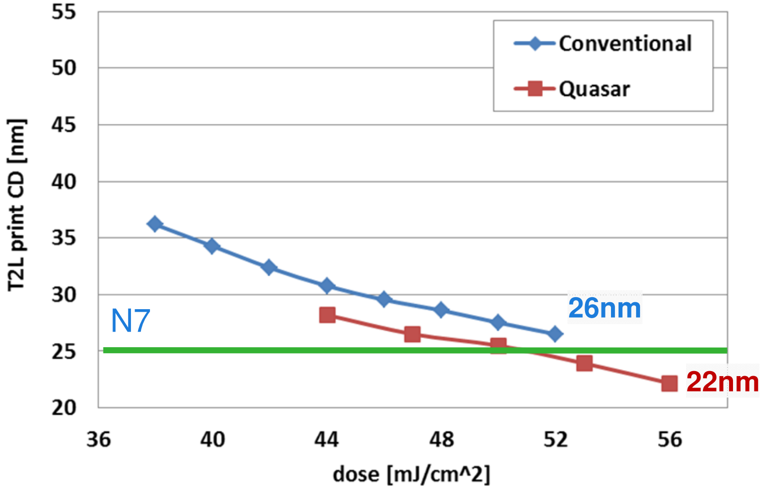
NXE3300: Line ends - tip2line minimum print gap size

tip2line printed gap size down to 22nm with Quasar illumination

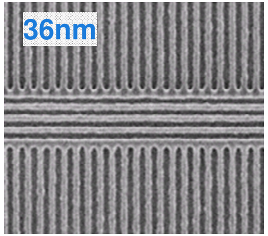
Lower dose resist, 22nm mask gap

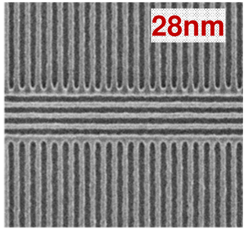


Higher dose resist, 22nm mask gap



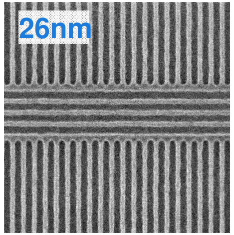
Conv.

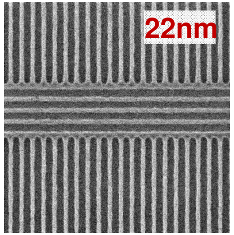




Quasar

Conv.



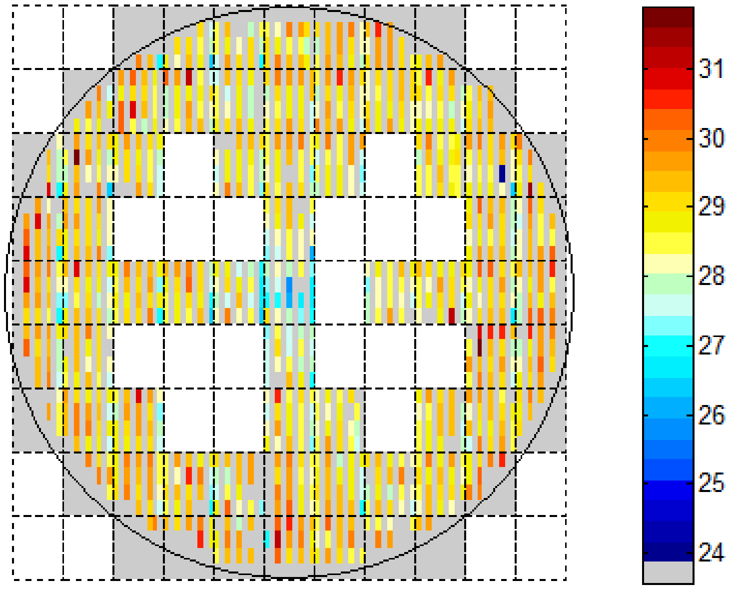


Quasar

NXE:3300 Tip2Line full wafer CD uniformity

CDU is in line with N10 logic metal layer requirements

NA=0.33, Quasar 45 illumination



Mask design gap CD: 20nm

- Average resist T2L CD: 28.8nm
- In combination with 22nm L/S grating

Full wafer CDU 2.5nm

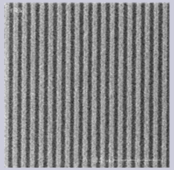
- 'Raw' data, no corrections
- Is in line with 10nm node requirement (10%)

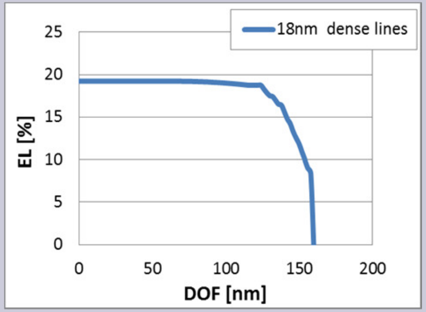
Contents

Large Process window for 18nm HP L/S

Dosemapper drives CDU to <1nm

Process window

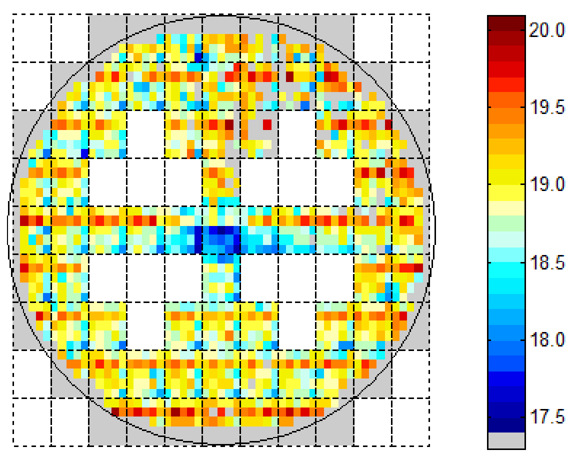




- EL 19%, DoF 160nm
- BE 36mJ

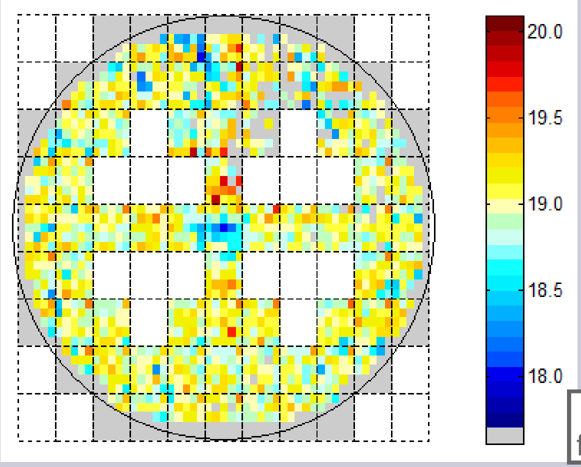
Full wafer CD uniformity

Raw data, no corrections



- Full wafer CDU 1.2nm 3σ
- Intra field CDU 0.9nm 3σ

DoseMapper corrected (prediction)

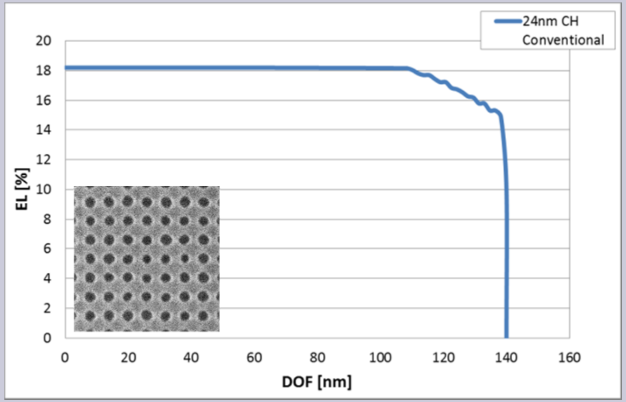
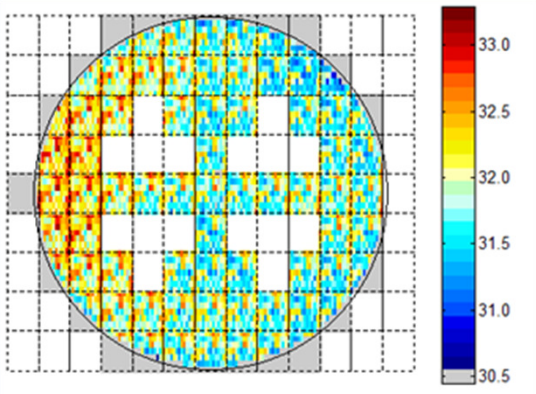


only NF fields shown

- Full wafer CDU 0.7nm 3σ
- Intrafield CDU 0.4nm 3σ

24nm HP regular C/H with conventional illumination

Large process window and 1.2nm FWCDU

Process Window	Full wafer CD uniformity
	
EL 18% DoF > 120nm	Full wafer CDU raw: 1.2nm 3σ Yieldstar measurements

NF fields shown
Raw data

- Raw data, no corrections. Dose 27mJ/cm2.
- Systematic fingerprints dominated by reticle and process

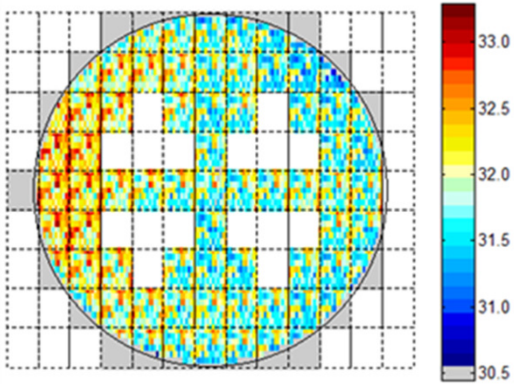
24nm HP regular C/H global vs local CDU

Local CDU becomes key metric for contact hole performance

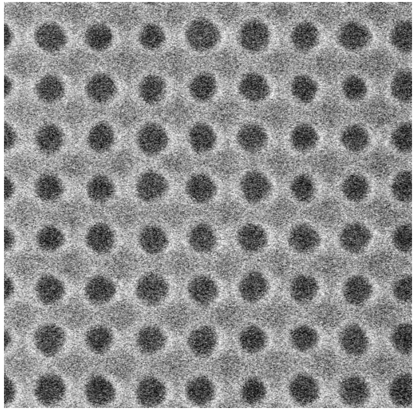
Public

24nm CH, Conventional ill.
27mJ resist

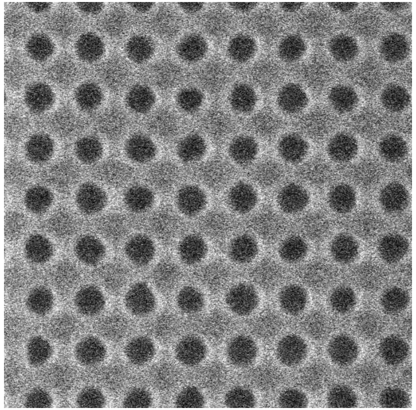
24nm CH, Small annular ill.
31mJ resist



Global CDU 1.2nm (3σ)



Local CDU 4.8nm (3σ)



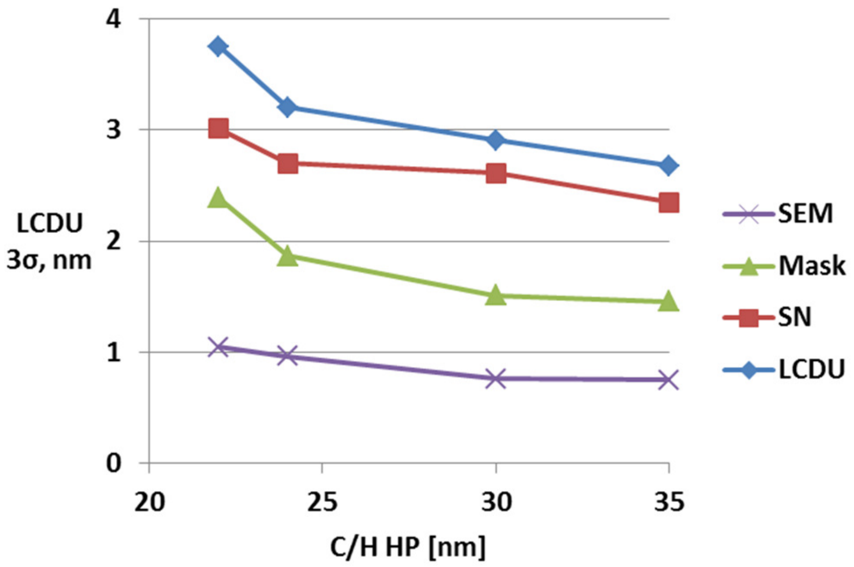
Local CDU 3.2nm (3σ)

- With decreasing CH sizes, local CDU is replacing global CDU as key metric for contact hole performance qualification

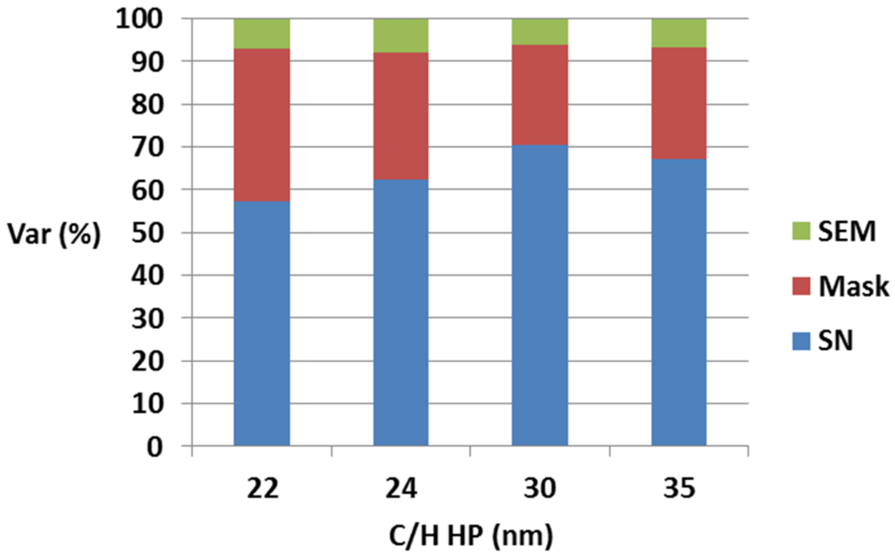
LCDU budget breakdown for regular contact holes

Shot noise is the main contributor

NA=0.33, Quasar45, 36-44mJ/cm^2

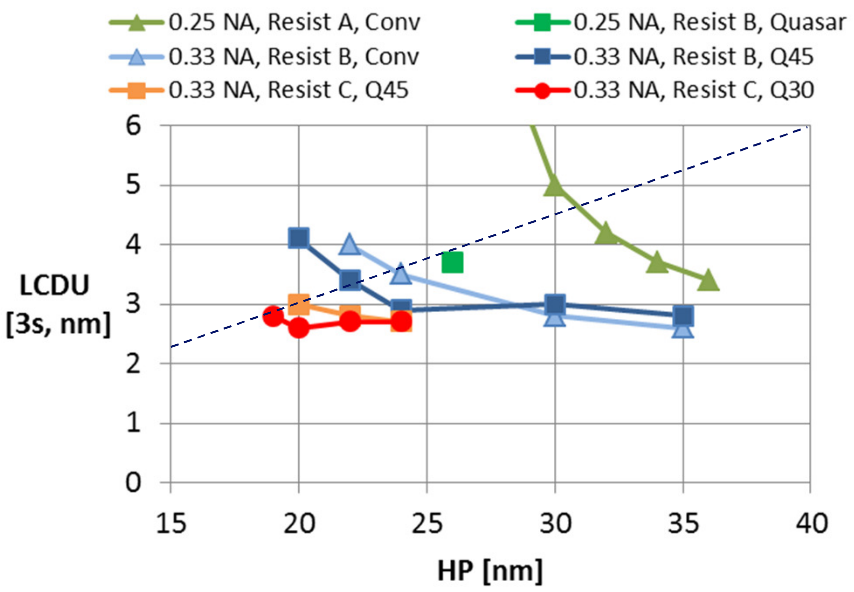


Shot noise: variance 60-70%
photon, acid, deprotection events



LCDU improves with NA, illumination and resist

Regular contact holes



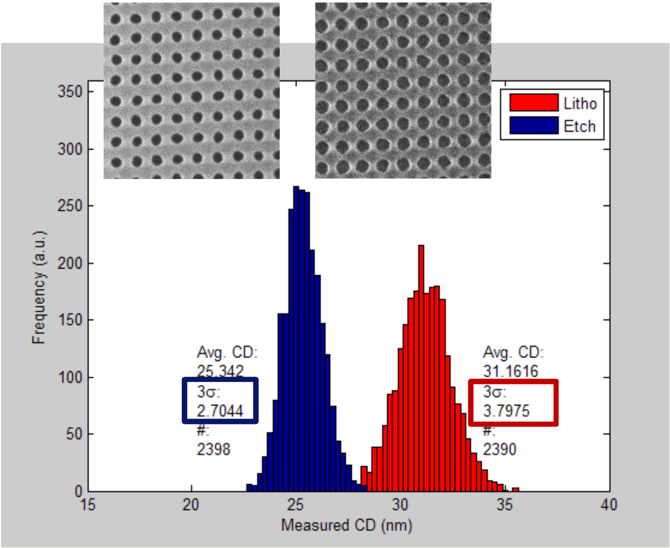
NA	Illum.	Resist	Dose mJ/cm2	HP <15%
0.25	Conv.	A	16	32
0.25	Quasar	B	27	26
0.33	Conv.	B	32	24
0.33	Quasar45	B	33	22
0.33	Quasar45	C	79	20
0.33	Quasar30	C	73	19

- In resist, w/o post-processing

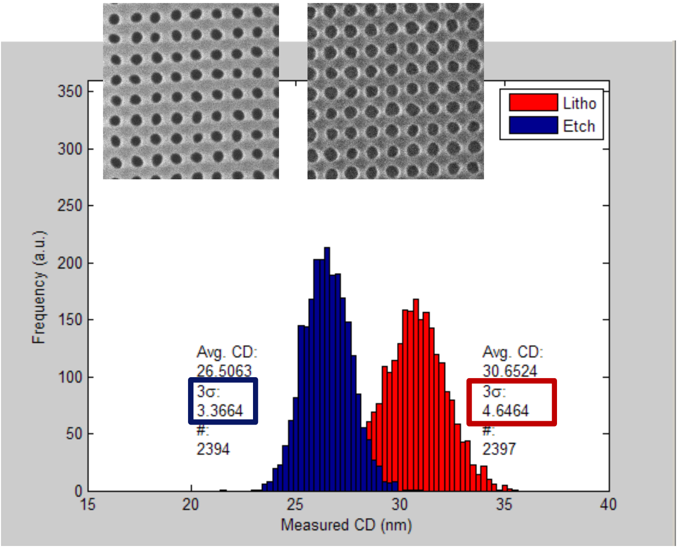
Post processing and etch can mitigate LCDU

26nm HP regular CH: Etch alone reduces LCDU with 30%

27.25mJ/cm² resist



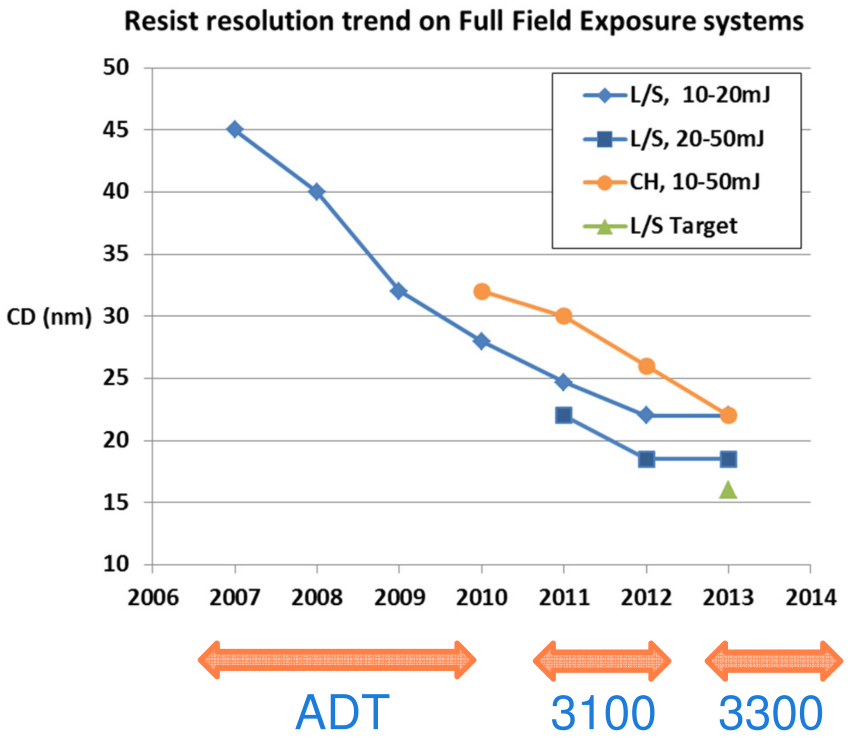
19.5mJ/cm² resist



- 26nm HP C/H, exposed with the NXE:3100
- Both wafers etched and measured with the same conditions
- LCDU reduction by etch ~30% for both resists

Contents

Photoresist progress on full field exposure systems
ADT, NXE:3100, NXE:3300 as measured by ASML/ IMEC



Resolution w/o post-processing

- C/H with <15% LCDU
- L/S with <20% LWR

Status L/S:

- 22nm ok <20mJ/cm2 (N10)
- No progress last year, gap to 16nm

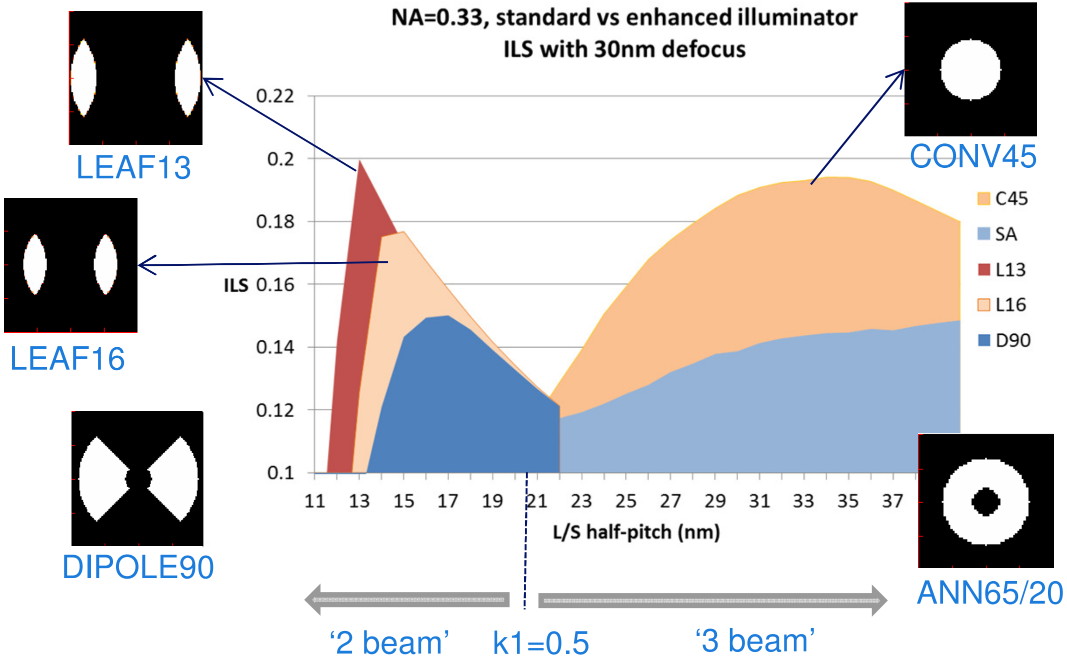
Status C/H:

- 22nm ok <40mJ/cm2

Contents

Major contrast improvements possible for 0.33 NA

Translating in lower dose requirements



Contrast improvements by:

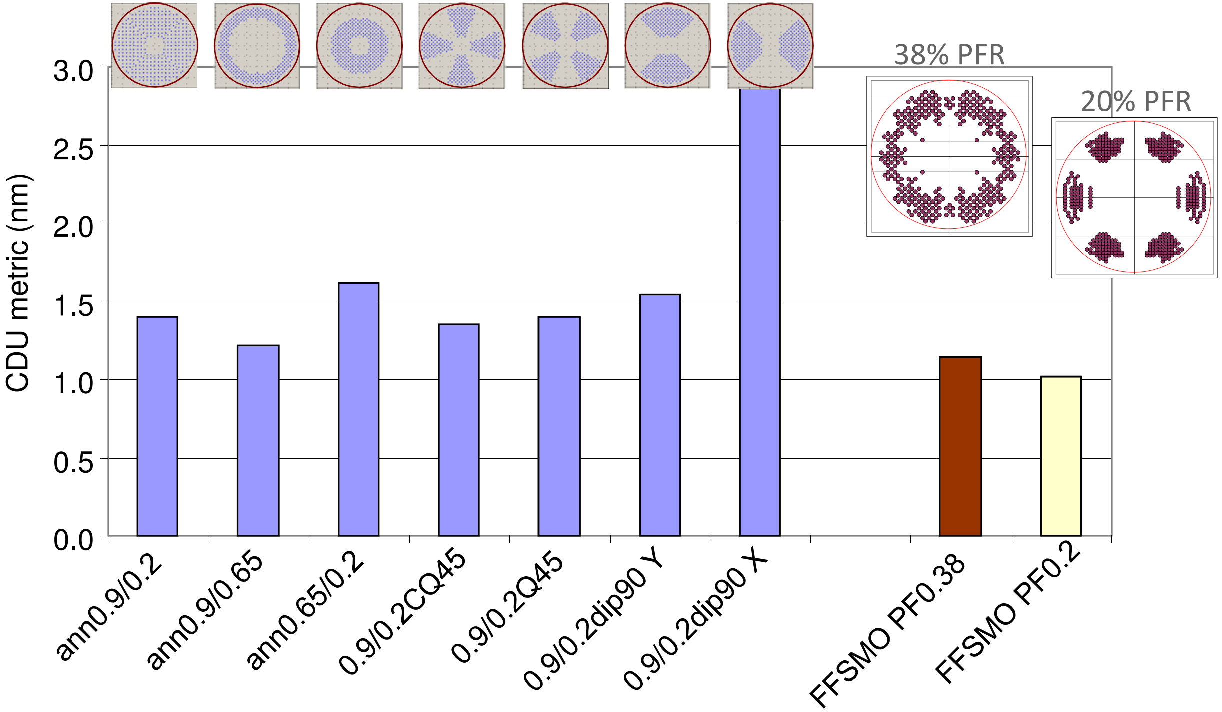
- Pupil fill ratio 0.38 → 0.2
- Sigma out 0.9 → 1.0
- Sigma in 0.2 → 0
- Lower dynamics, flare, aberrations

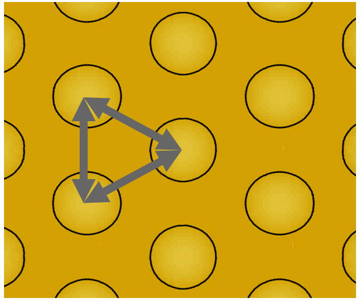
Translating into improved:

- Resolution, process window
- LWR/ LCDU
- Dose-to-size

Impact of illumination for Honeycomb C/H

Full flex SMO can reduce CDU with >20%





Pitch: 34nm

CDU gain Full Flex SMO:

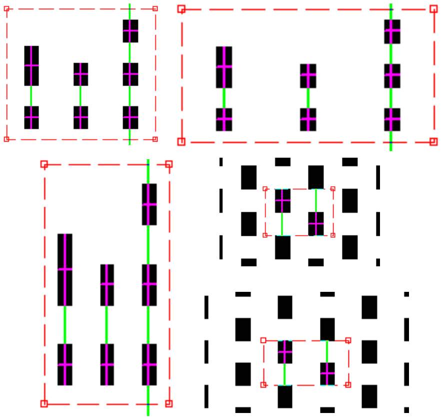
- PFR 38% ~10%
- PFR 20% ~25%
  - Lossless with 0.2 PFR illuminator

NXE:33x0B standard OAI vs FlexPupil imaging

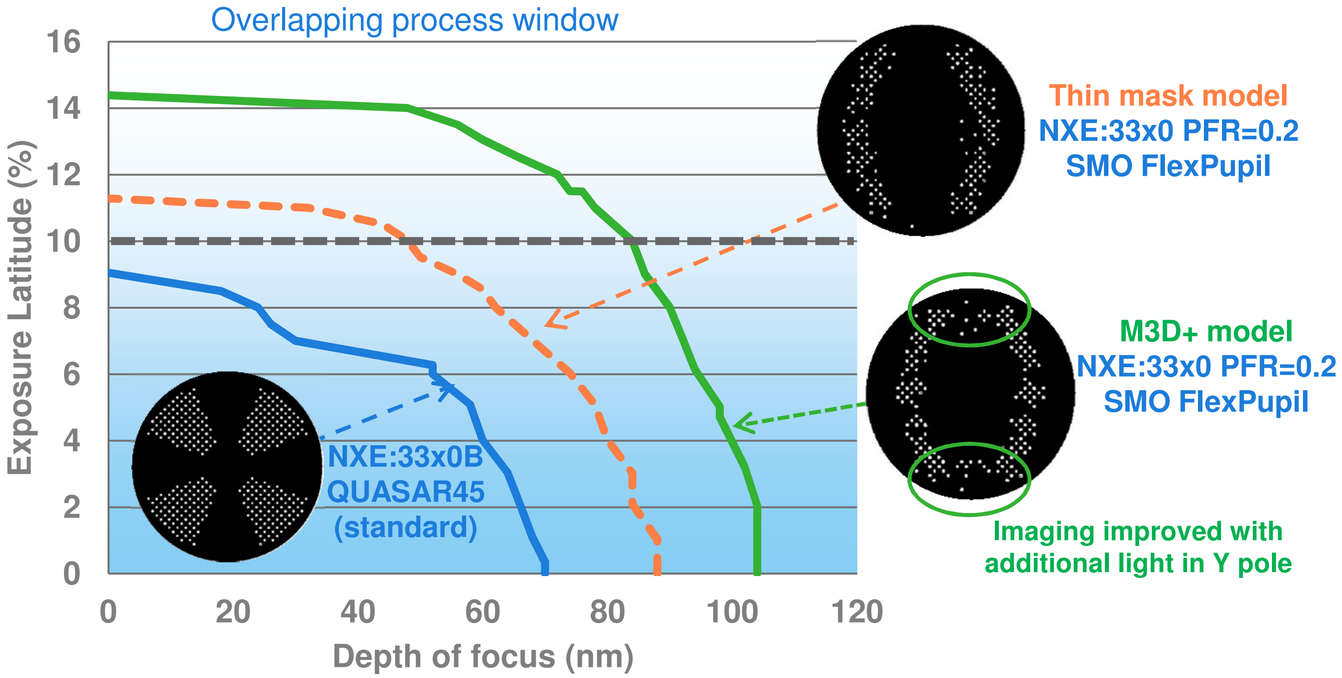
Tachyon SMO and NXE M3D+ deliver maximum process window

- FlexPupil enables custom pupil shapes on NXE:33x0B and future NXE scanners
- Tachyon SMO optimizes illumination using EUV mask and scanner models (M3D+, FlexPupil)

MPU 7 nm node example



- Bright field, cut mask (5 clips)
- Min CD: 14 nm
- Min space: 22 nm
- Tachyon NXE M3D+ model



Contents

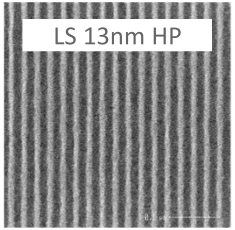
Summary

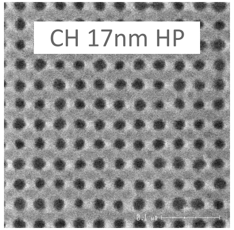
Excellent imaging performance shown for:

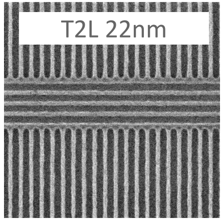
- DRAM applications (1D L/S, 2D C/H)
  - CDU is in line with 24nm HP SN requirements
- Logic metal applications (random 2D logic, line-ends)
  - CDU is in line with N10 requirements

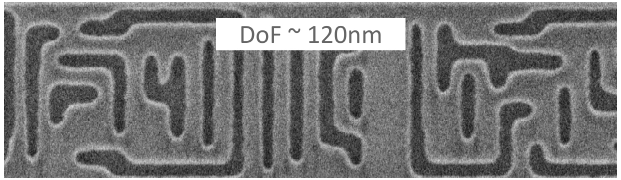
Continued resist progress is needed

Flexpupil will significantly improve the imaging performance









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

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

Special thanks to:

- ASML: Guido Schiffelers, Eelco van Setten, Eleni Psara, Liesbeth Reijnen, Joep van Dijk, Timon Fliervoet, Joost Hageman, Sjoerd Lok, Jo Finders
- IMEC: Jan Hermans, Ming Mao

Thank you for your attention !