EUV resist performance up-date on ADT and NXE:3100 scanner

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On assignment from [1]Micron, [2]Elpida

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INTRODUCTION

EUV RESIST PROJECT AT IMEC

ASML EUV ADT (NA=0.25, σ 0.5) 2008-2011

ASML NXE:3100 (NA=0.25, σ 0.8) 2011

- **Resist screening and benchmarking on ASML EUV ADT since 2008**
  - Follow up the performance of EUV resist and steer the progress in EUV resist
  - Select and optimize baseline resist processes to be used in the imec EUV program for NXE:3100 and for device implementation.
- **NXE:3100 recently became fully operational and resist performance benchmarking on NXE:3100 has started.**

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RESIST PERFORMANCE TARGET FOR 2011 ON ADT and NXE:3100

28nm-27nm

Targets on the ADT conventional ill sigma 0.5	2011
Ultimate resolution-resolved HP	26nm
Resolution Line/Spaces HP(nm) DOF for 1:1 L/S at 10% EL Maximum EL	27nm 100nm >10%
LER on 28nm L/S (nm 3sig)	3.5nm
Dose-to-size at 28nm L/S (mJ/cm^2)	<15
Resolution Contacts 1:1 (nm) Max DOF Max EL LCDU at 30nm HP (1sigma)	30nm >120nm >10% <1.0nm
Resist Thickness (nm)	50nm LS 60nm CH

25-22nm

Resist PerformanceTarget NXE:3100	H2 2011
Ultimate resolution-resolved HP With 60 Degree Dipole With Extreme Dipole	 22nm 18nm
Resolution L/S 1:1 (nm) With 60 Degree Dipole Ilumination DOF@10%EL dose-to-size LER on 25nm L/S	25nm >100nm <15mJ 3.0nm
Resolution Contacts 1:1 (nm) DOF@10%EL With Quasar Ilumination LCDU at 28nm HP	26nm >100nm <1.0nm
Resist Thickness (nm)	40-50nm

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OUTLINE

Introduction

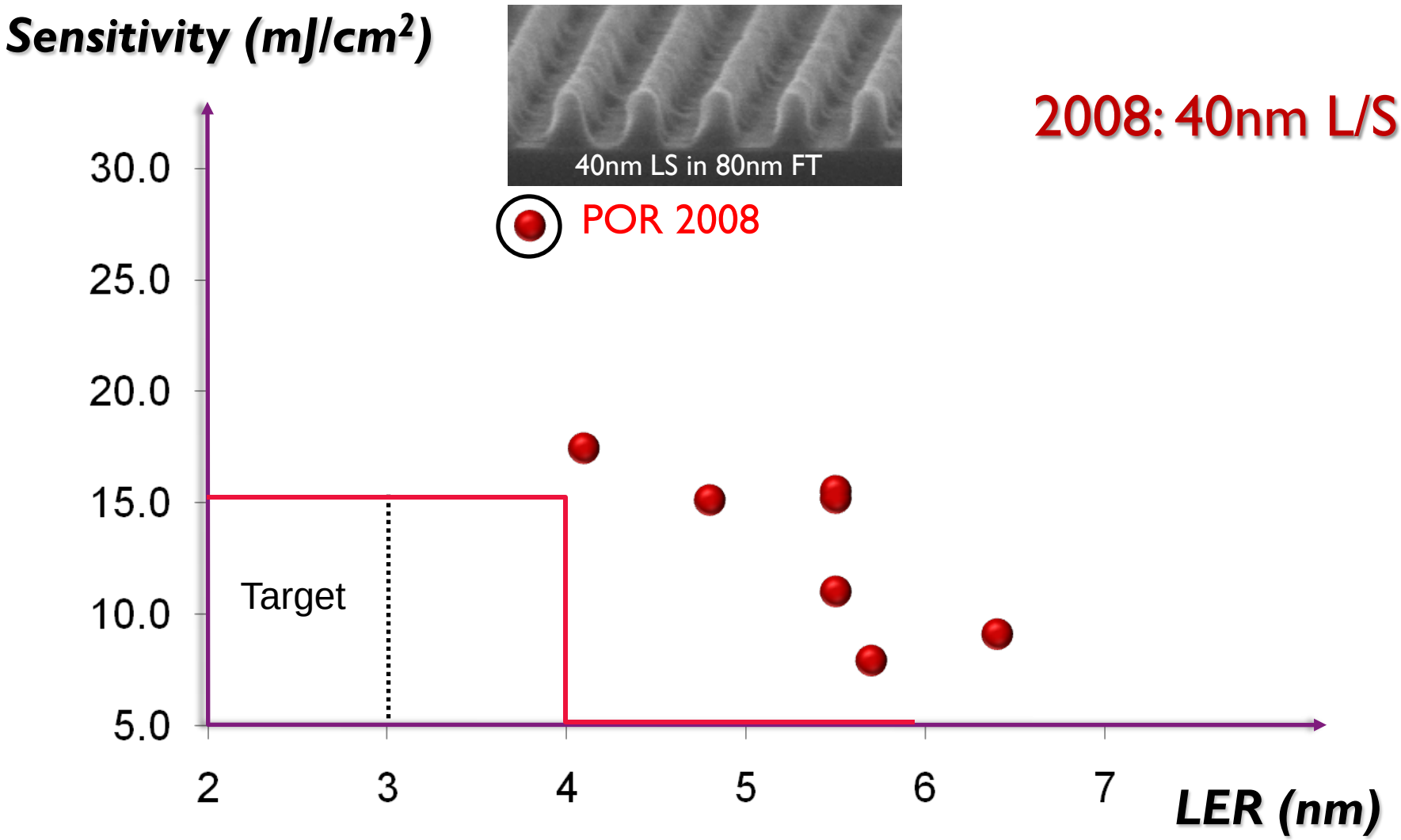
Resist performance on ADT

- Line / Space results
- Contact hole performance

Resist performance on NXE:3100

Summary

EUV RESIST PROGRESS



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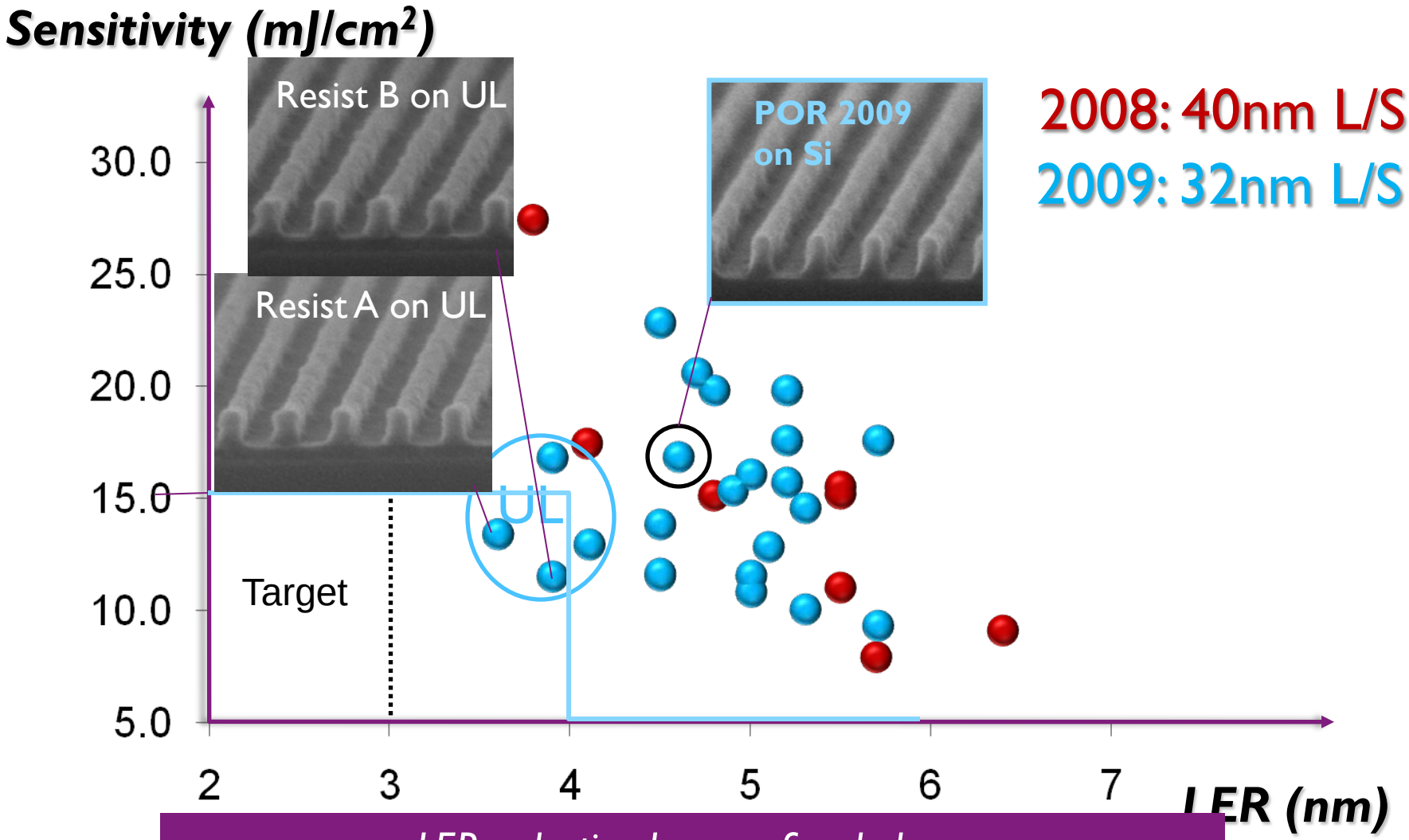
EUV RESIST PROGRESS



LER reduction by use of underlayer

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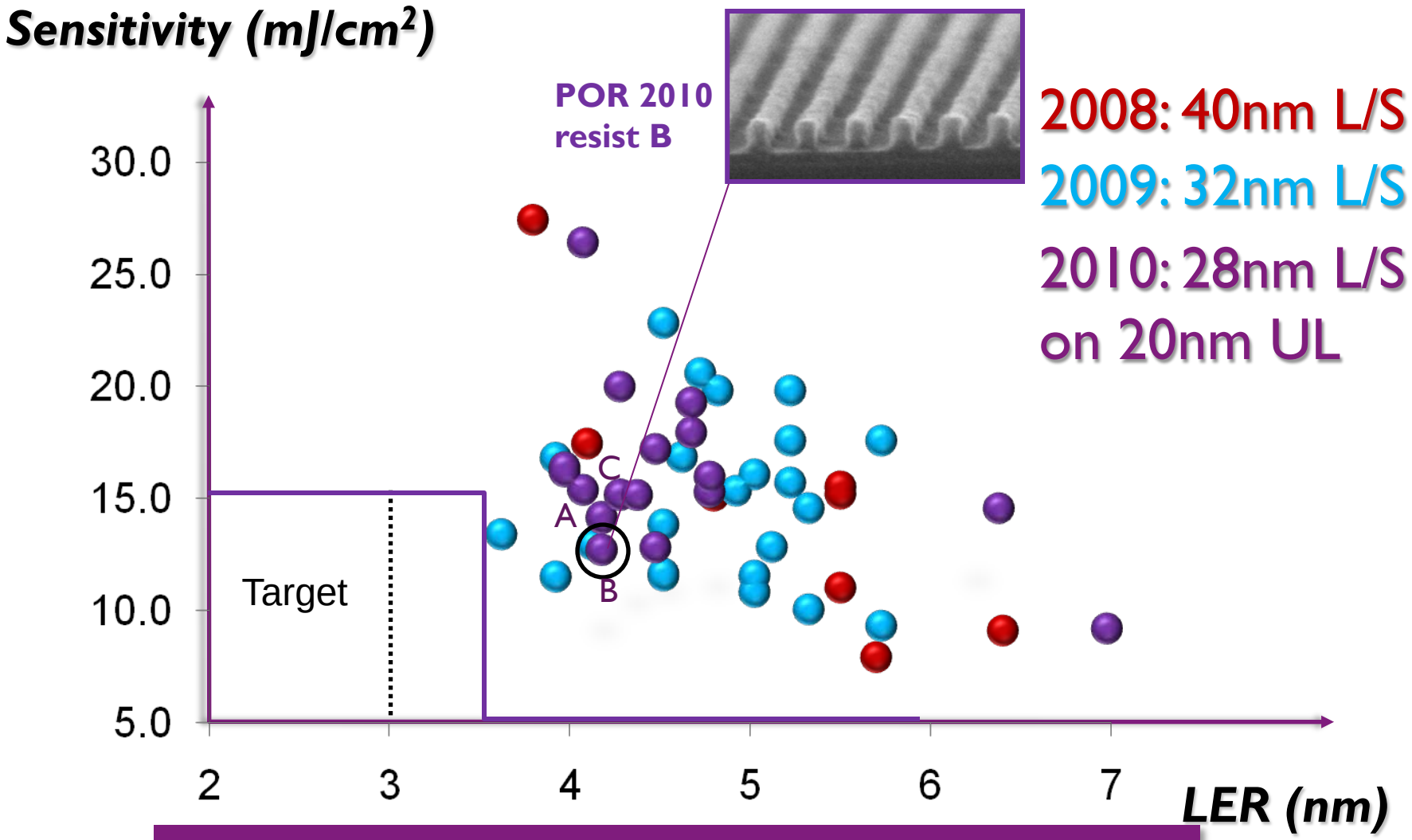
EUV RESIST PROGRESS



Resists A,B,C installed on track and detailed benchmarking

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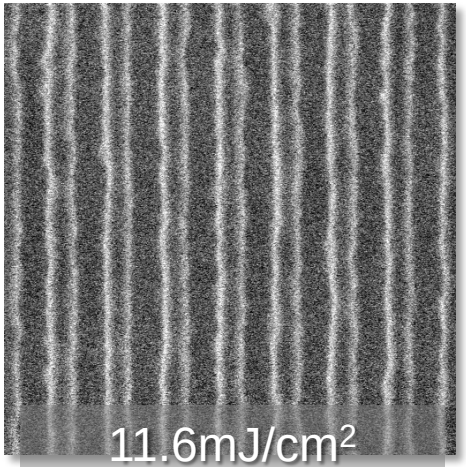
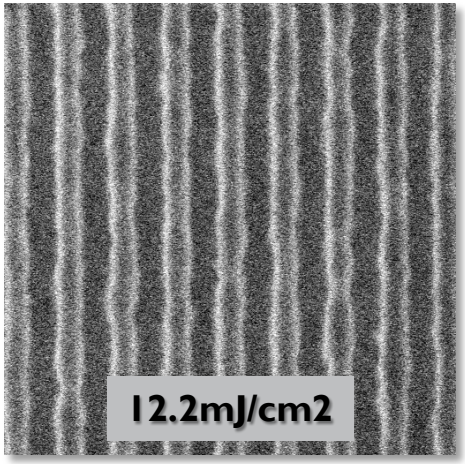
EUV RESIST PERFORMANCE @ ADT

IMEC POR RESIST RESIST B, 50nm THICKNESS ON UNDERLAYER

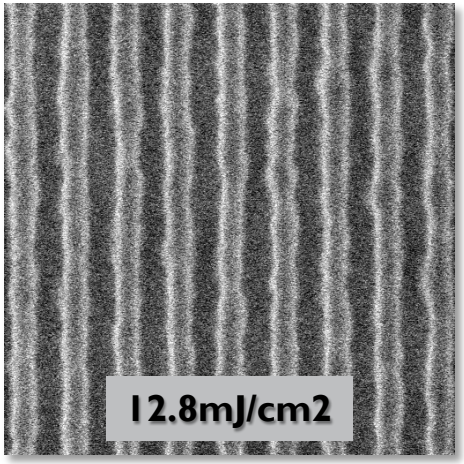
28nm L/S



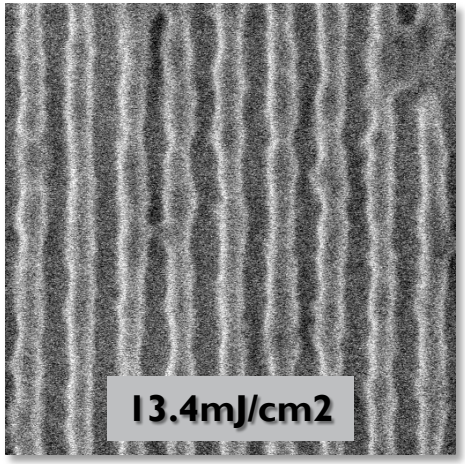
27nm L/S

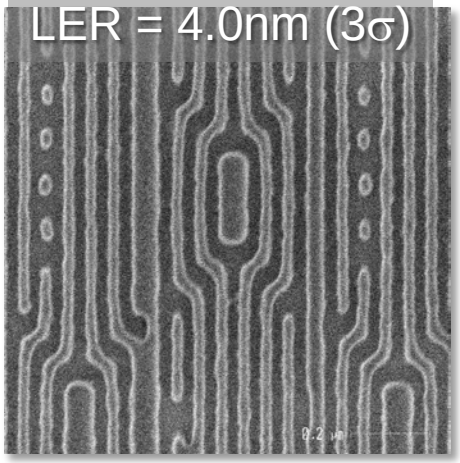


26nm L/S

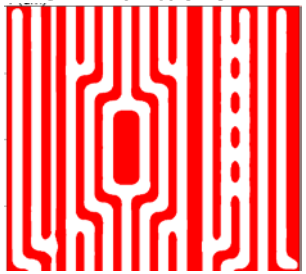


25nm L/S



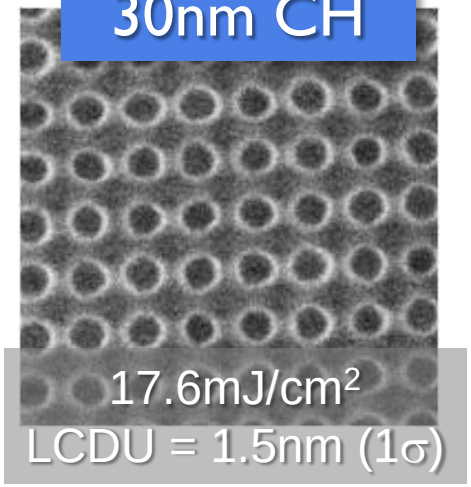


Simulation



0.25NA, 0.5sigma

30nm CH



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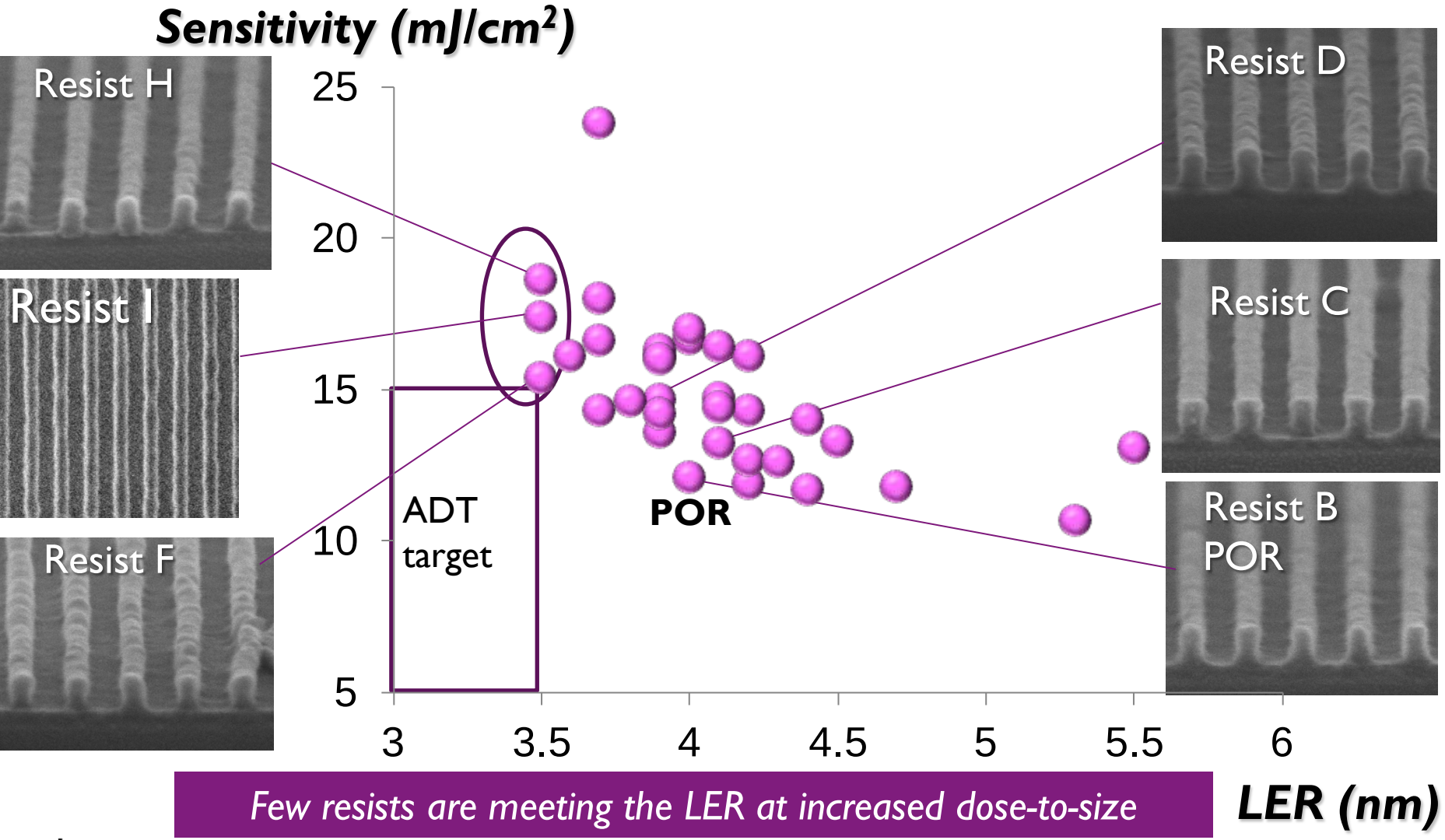
RESIST SCREENINGS ON ADT IN 2011
28NM LS, NA=0.25, σ=0.5



Few resists are meeting the LER at increased dose-to-size

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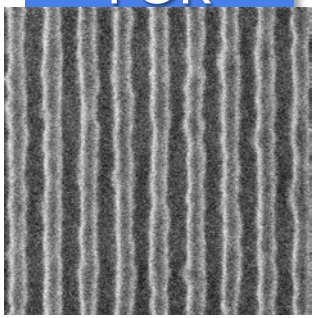
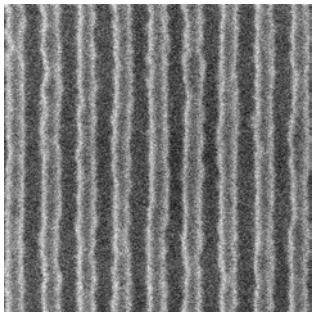
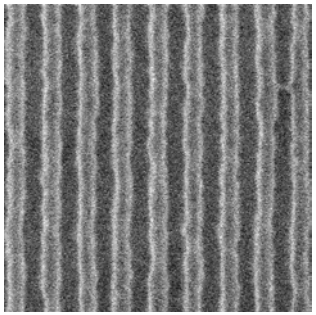
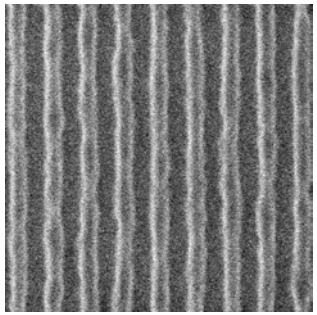
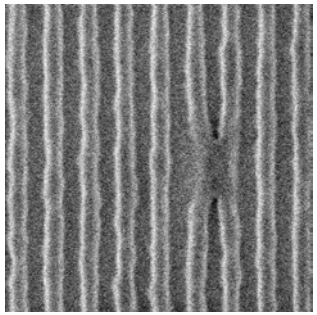
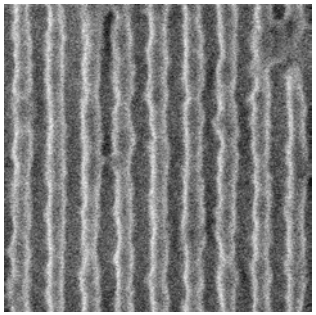
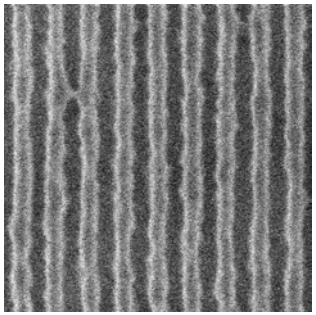
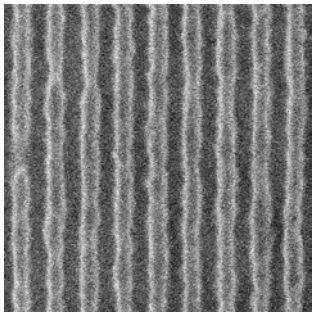
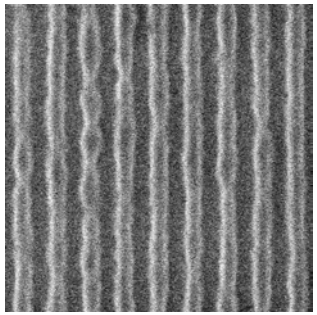
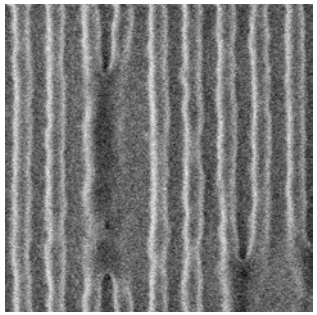
ULTIMATE RESOLUTION ON ADT
ADT EXPOSURE, RESIST THICKNESS 50NM

	Resist B POR	Resist C	Resist D	Resist E	Resist F
26nm					
	12.8mJ/cm2	13.8mJ/cm2	15.5mJ/cm2	16.2mJ/cm2	16.6mJ/cm2
25nm					
	13.4mJ/cm2	14.4mJ/cm2	16.2mJ/cm2	16.9mJ/cm2	17.8mJ/cm2

26nm HP is clearly resolved in most resist
pattern collapse is limiting the resolution for resist F

NA=0.25,σ0.5

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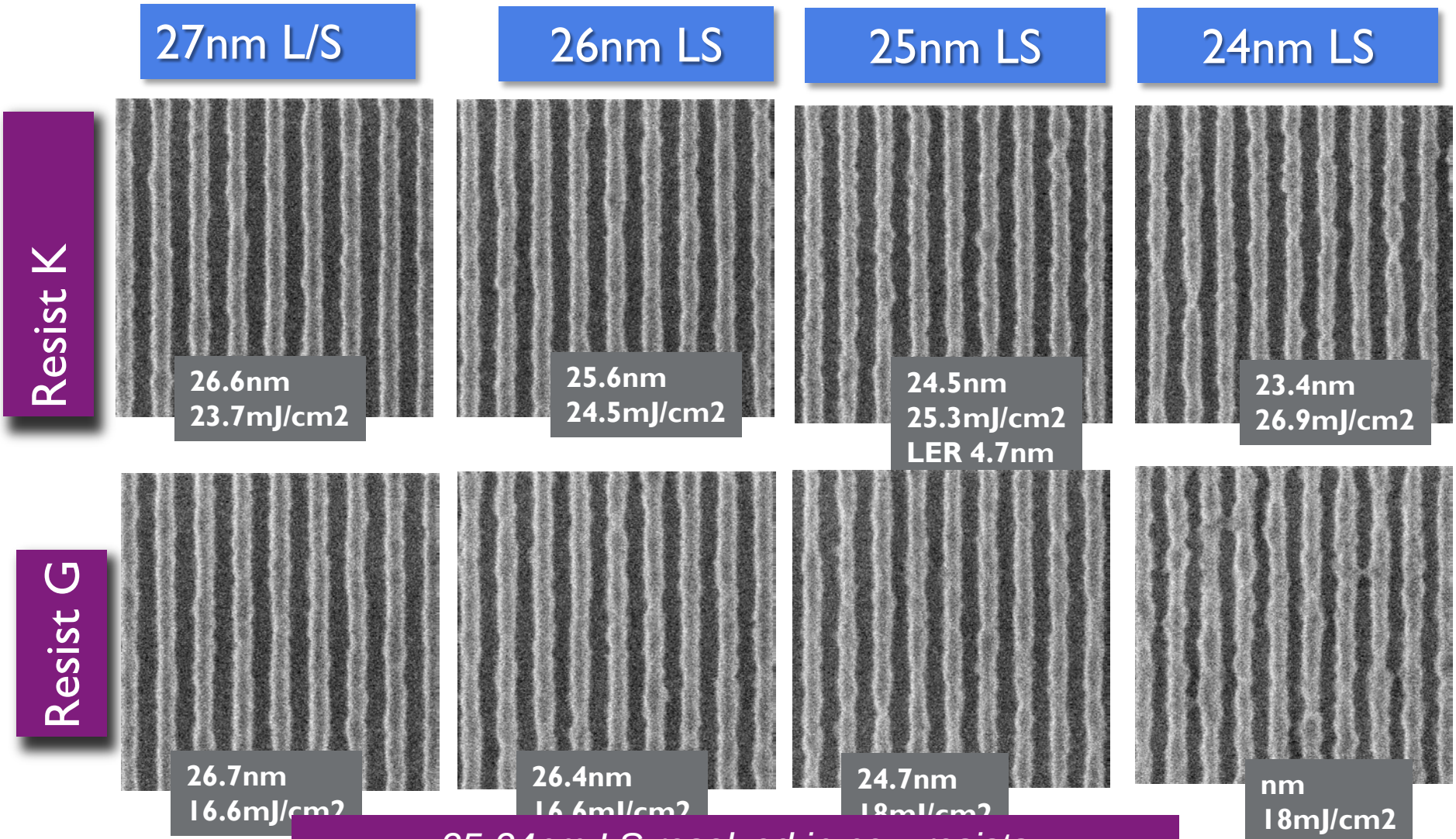
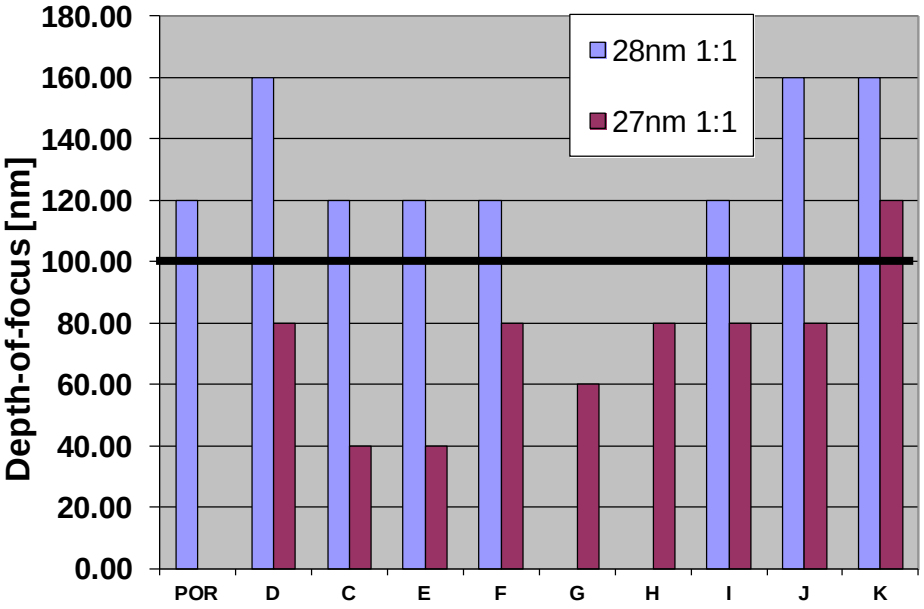
SUB-26 NM RESOLUTION CHAMPION DATA ON ADT (NA=0.25, σ=0.5)



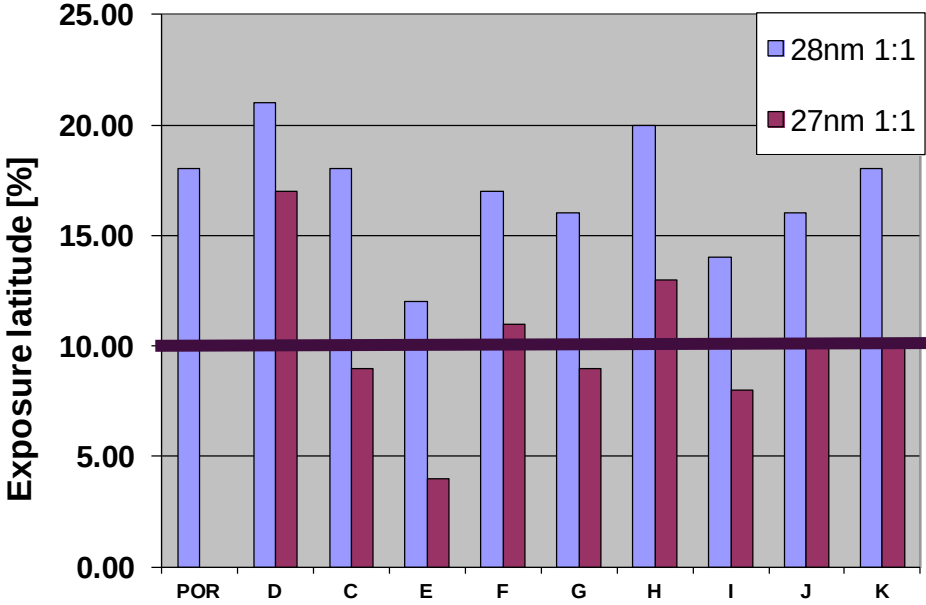
25-24nm LS resolved in new resists with conventional illumination on ADT but high dose

PROCESS WINDOWS OF PROMISING MATERIALS ON ADT (NA=0.25, σ=0.5)

Max DOF



Max Exposure latitude



Target spec of 100nm DOF and 10% EL is met for all resist for 28nm LS, but at 27nm LS especially the DOF target is challenging

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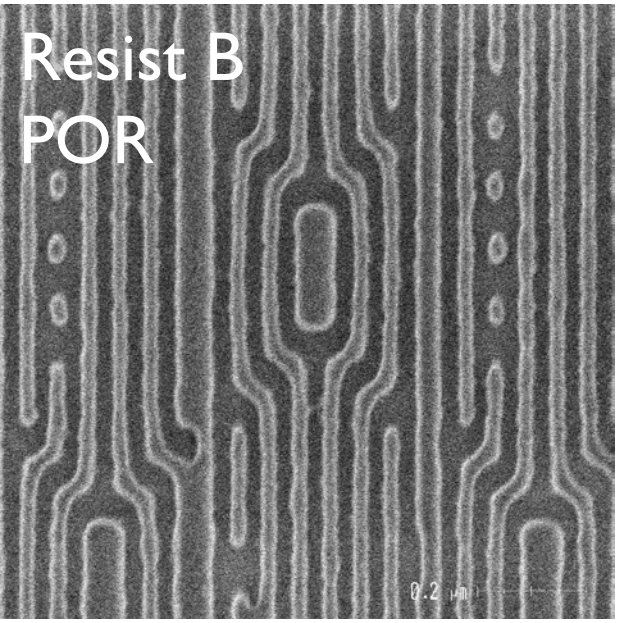
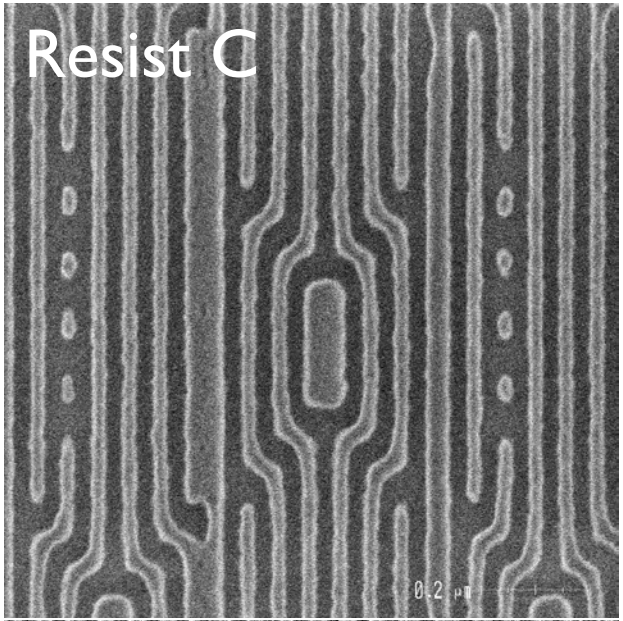
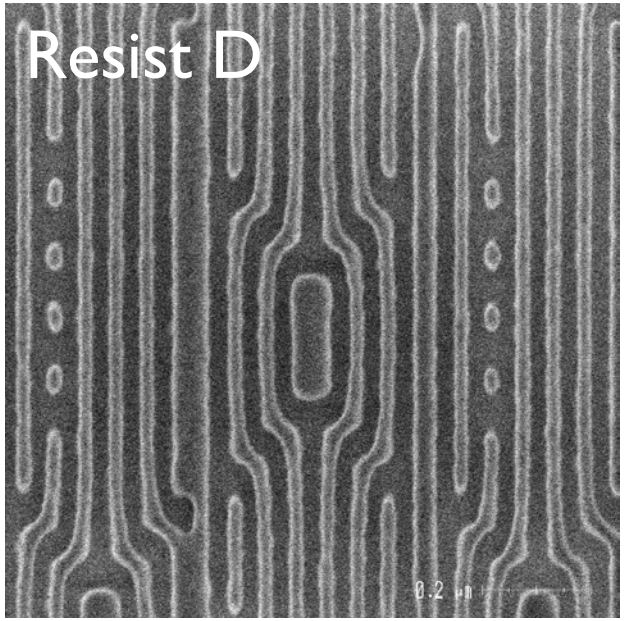
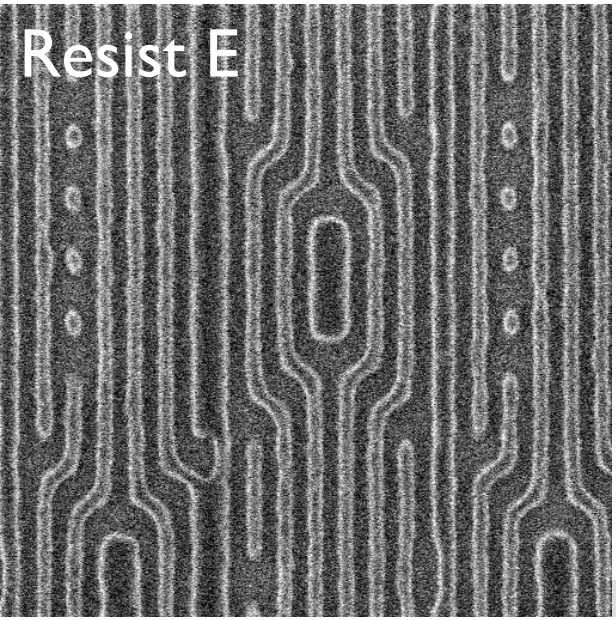
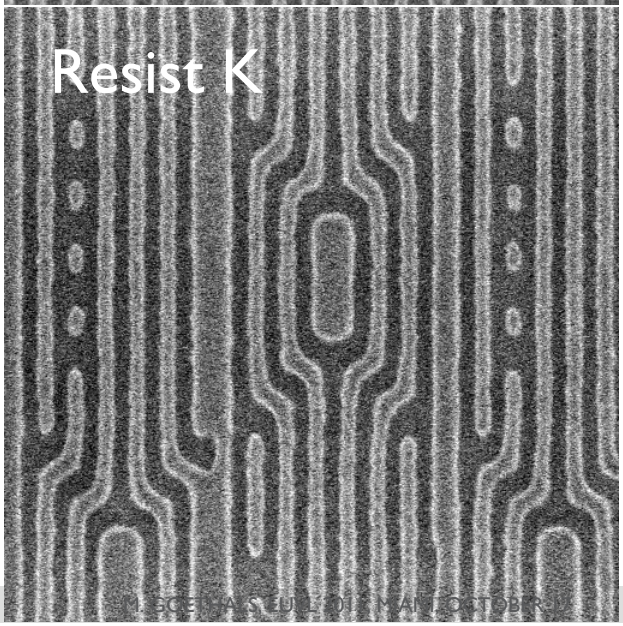
2D PATTERNS 28nm HP (ADT)



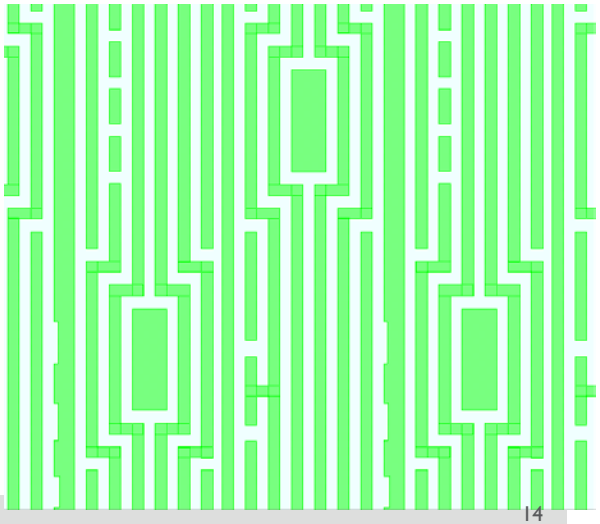




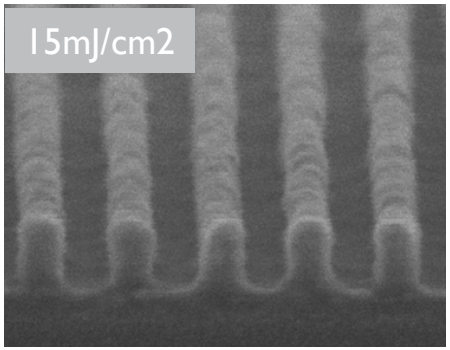
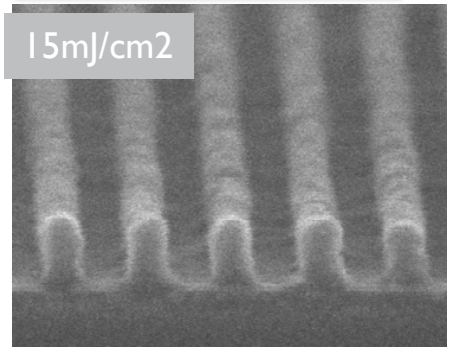
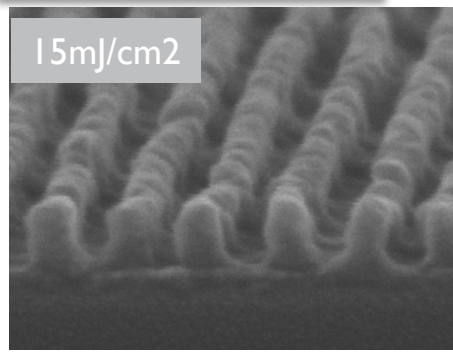
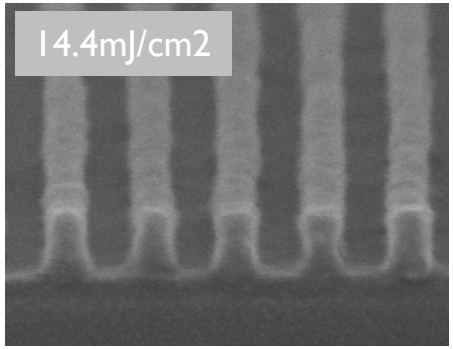
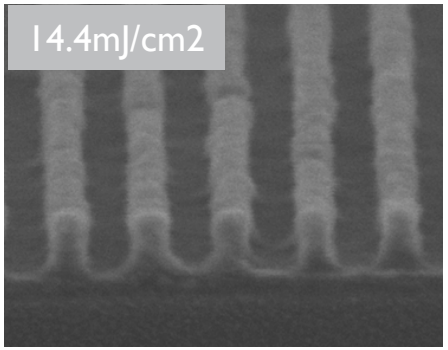
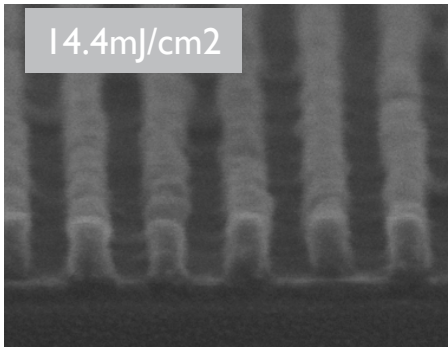
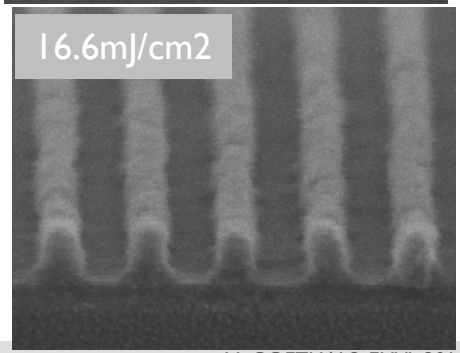
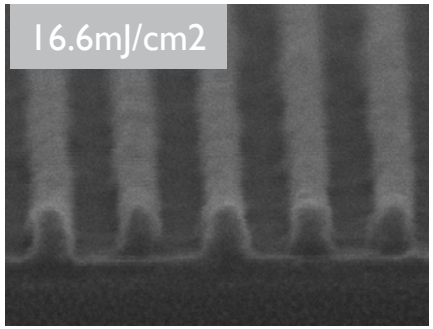
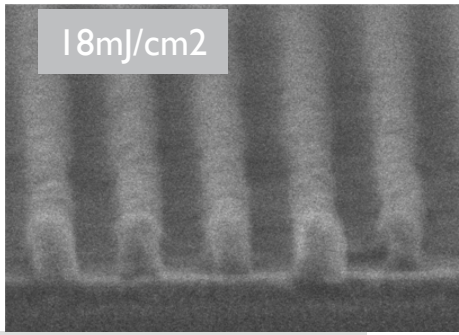




Mask Pattern



STATE OF THE ART RESIST PERFORMANCE ON ADT
X-SECTIONS

	27nm LS	26nm LS	25nm LS
Resist D	 15mJ/cm2	 15mJ/cm2	 15mJ/cm2
Resist C	 14.4mJ/cm2	 14.4mJ/cm2	 14.4mJ/cm2
Resist G	 16.6mJ/cm2	 16.6mJ/cm2	 18mJ/cm2

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OUTLINE

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Resist performance on ADT

- Line / Space results
- **Contact hole performance**

Resist performance on NXE:3100

Summary

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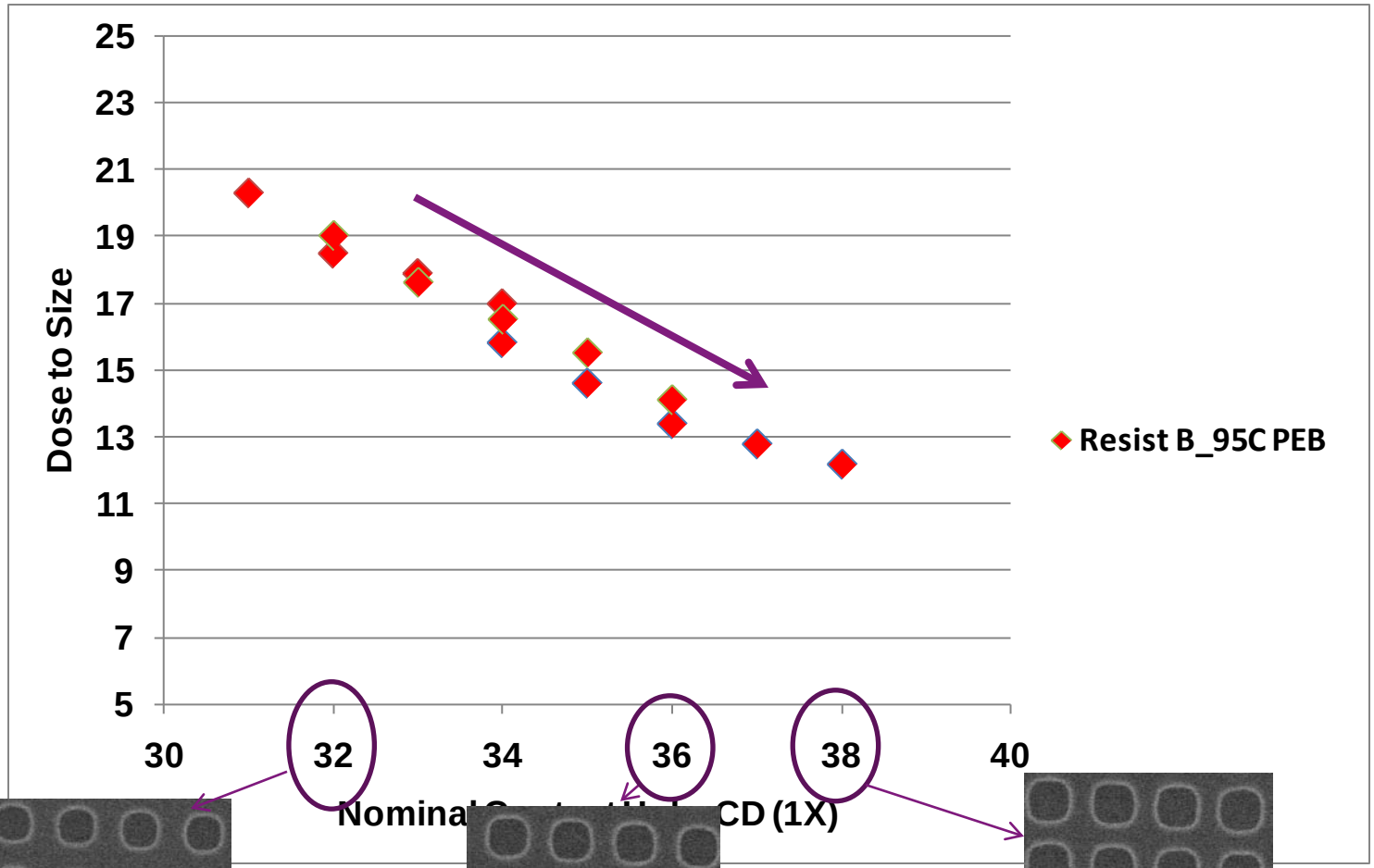
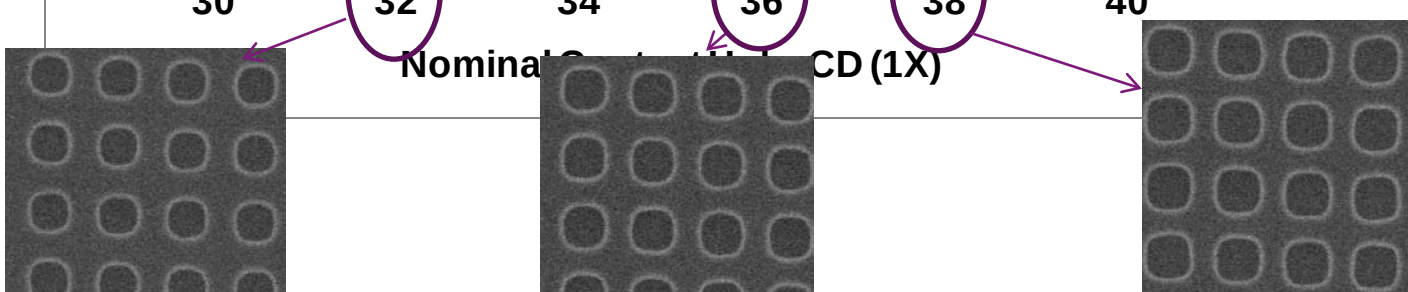
30NM HP CONTACT VS MASK BIAS



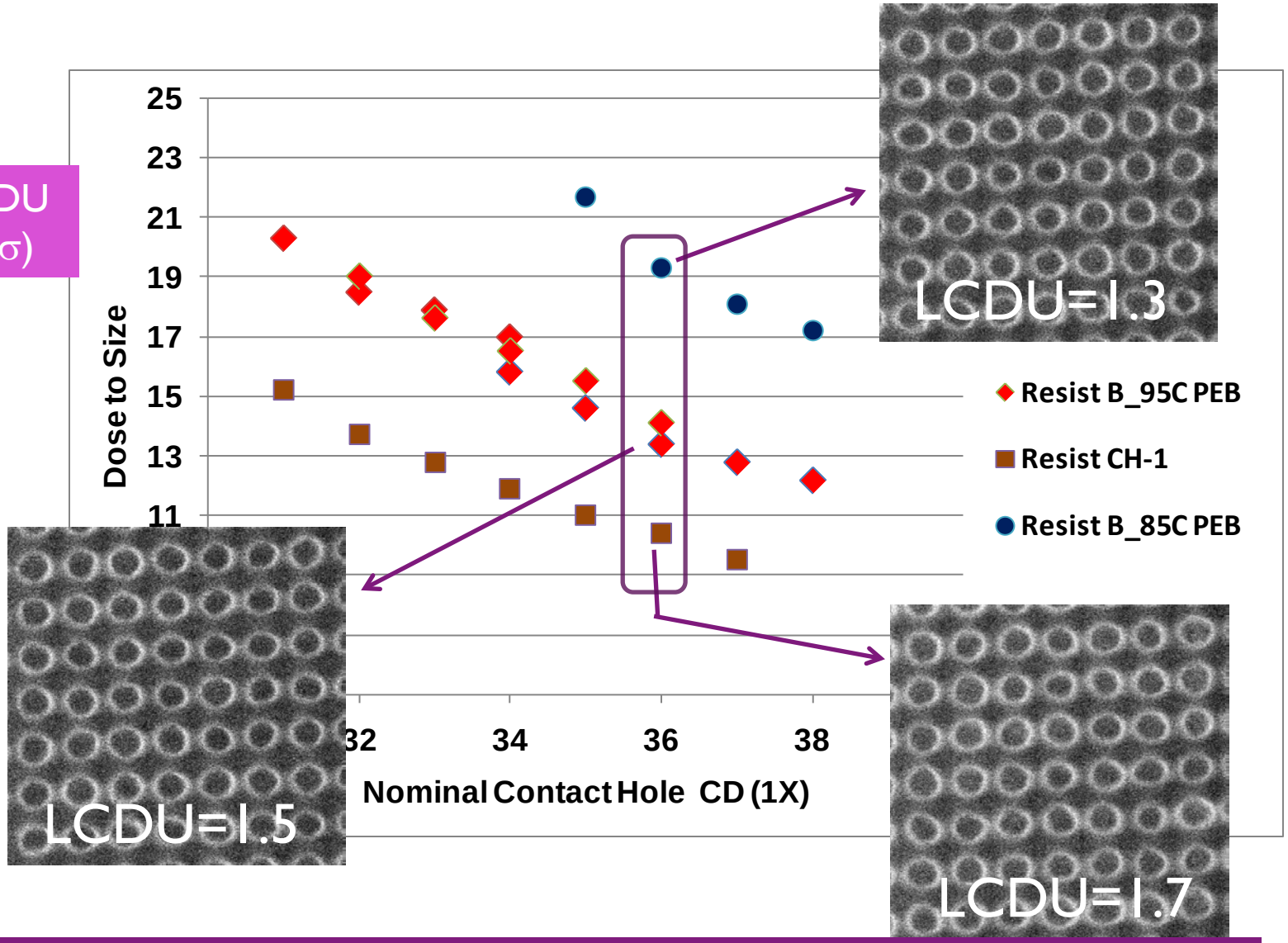
Mask



Lower dose to size with increasing mask CD (bias)

30NM HP CONTACT VS MASK BIAS

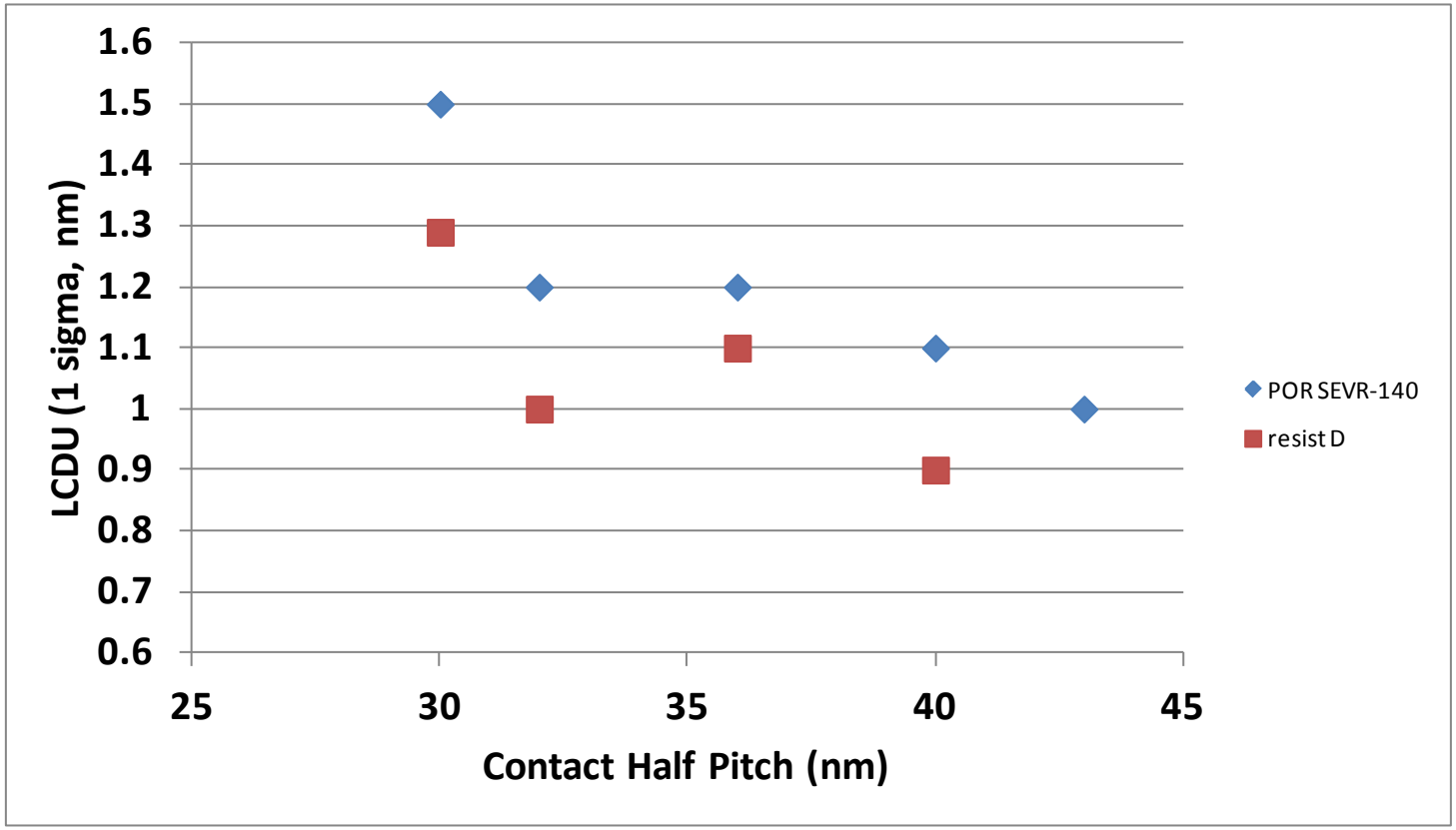
Target LCDU <1.0nm (1σ)



Slower resist or process results in better (lower) LCDU
Shot noise contributor to LCDU

LOCAL CDU FOR LARGER HP CONTACTS

RESIST B AND RESIST D



Local CDU levels off at 0.9nm (1σ)
Higher image contrast at larger contacts might contribute reduction in LCDU

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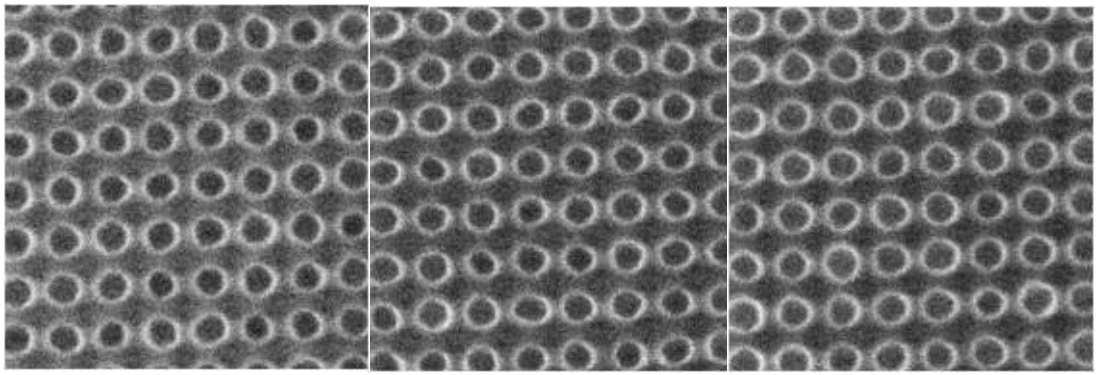
30nm HP CH. RESIST B
HOLE BIAS ON MASK +10%, +20%, +25%

	C33P60(+10%)	C36P60(+20%)	C38P60(+25%)
Dose-to-size	17.6mJ/cm2	13.7mJ/cm2	12.3mJ/cm2
1 sigma LCDU	1.4nm	1.5nm	1.5nm
Max Exp latitude (≥ 15%)	19.1%	21.0%	18.8%
Max DOF (≥ 120nm)	160nm	160nm	150nm
DOF at 10% EL	160nm	160nm	120nm
Exp latitude at 150nm DOF	18%	14.0%	1.0%

60nm Resist thickness
ADT Exposure
conventional illumination



+10% bias slight advantage with regard to LCDU
optimum bias between 10% and 20%

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Resist performance on NXE:3100

Summary

NXE:3100 CLUSTER AT IMEC

ASML NXE:3100
XTREME DPP source

TEL CLEAN TRACK™
LITHIUS Pro™ -EUV

Poster session
Ph. Foubert "EUV baseline process optimization"

RESIST PERFORMANCE TARGET FOR 2011 on NXE:3100

ADT 28-27nm

Targets on the ADT conventional ill sigma 0.5	2011
Ultimate resolution-resolved HP	26nm
Resolution Line/Spaces HP(nm) DOF for 1:1 L/S at 10% EL Maximum EL	27nm 100nm >10%
LER on 28nm L/S (nm 3sig)	3.5nm
Dose-to-size at 28nm L/S (mJ/cm^2)	<15
Resolution Contacts 1:1 (nm) Max DOF Max EL LCDU at 30nm HP	30nm >120nm >10% <1.0
Resist Thickness (nm)	50nm LS 60nm CH

NXE 25-22nm

Resist PerformanceTarget NXE:3100	H2 2011
Ultimate resolution-resolved HP With 60 Degree Dipole With Extreme Dipole	 22nm 18nm
Resolution L/S 1:1 (nm) With 60 Degree Dipole Ilumination DOF@10%EL dose-to-size LER on 25nm L/S	25nm >100nm <15mJ 3.0nm
Resolution Contacts 1:1 (nm) DOF@10%EL With Quasar Ilumination LCDU at 28nm HP	26nm >100nm <1.0nm
Resist Thickness (nm)	40-50nm

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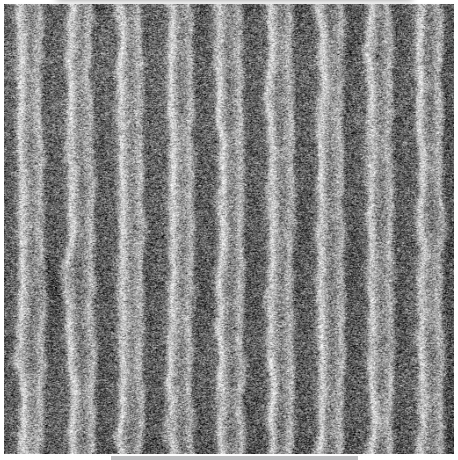
EUV RESIST PERFORMANCE ON NXE3100

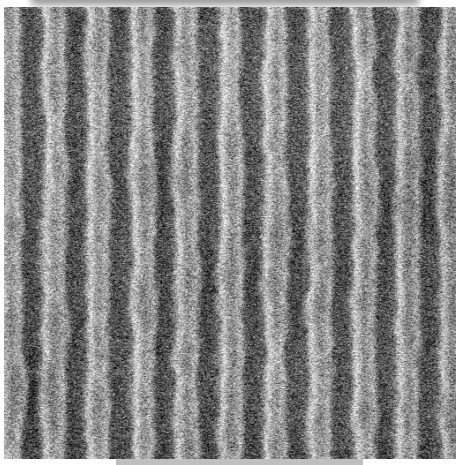
DIPOLE ILLUMINATION, 40NM IMEC POR RESIST ON UL

25nm LS



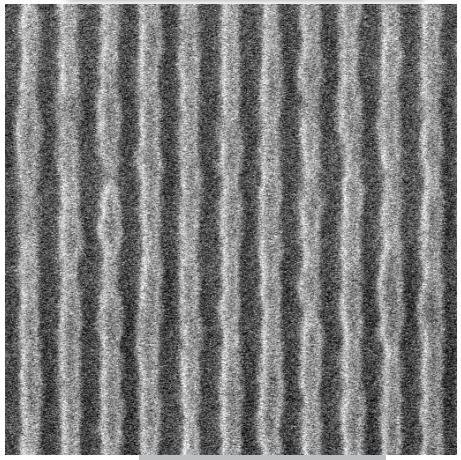
12.5mJ/cm2
4.0nm LER

22nm LS



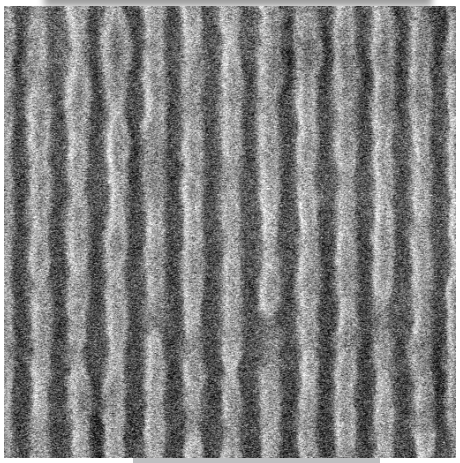
13.4mJ/cm2
4.7nm LER

20nm LS



14.6mJ/cm2

19nm LS



15.2mJ/cm2

Sub-22nm resolution demonstrated by the using dipole illumination

ASML

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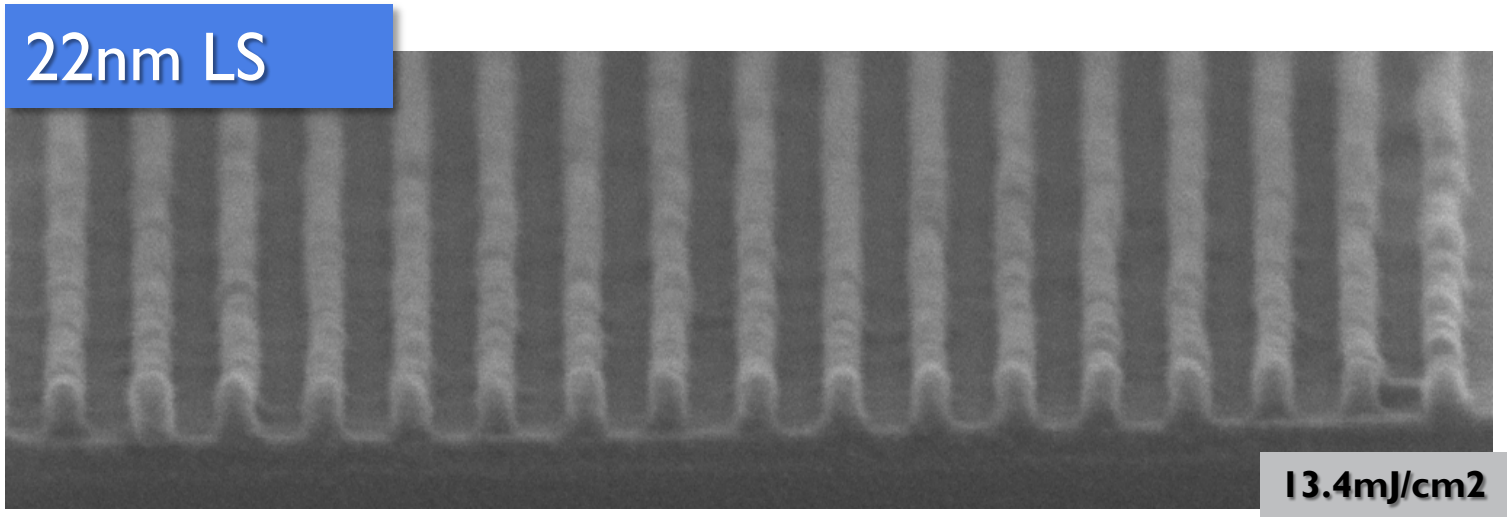
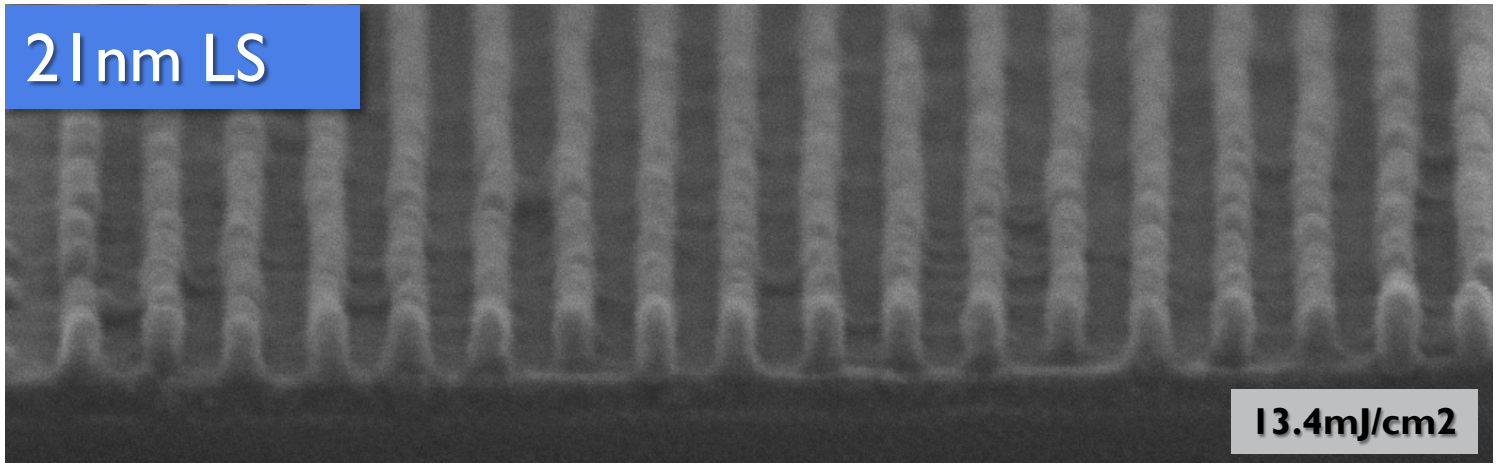
NXE:3100 ULTIMATE RESOLUTION

DIPOLE ILLUMINATION, 40NM RESIST B ON UL X-SECTIONS





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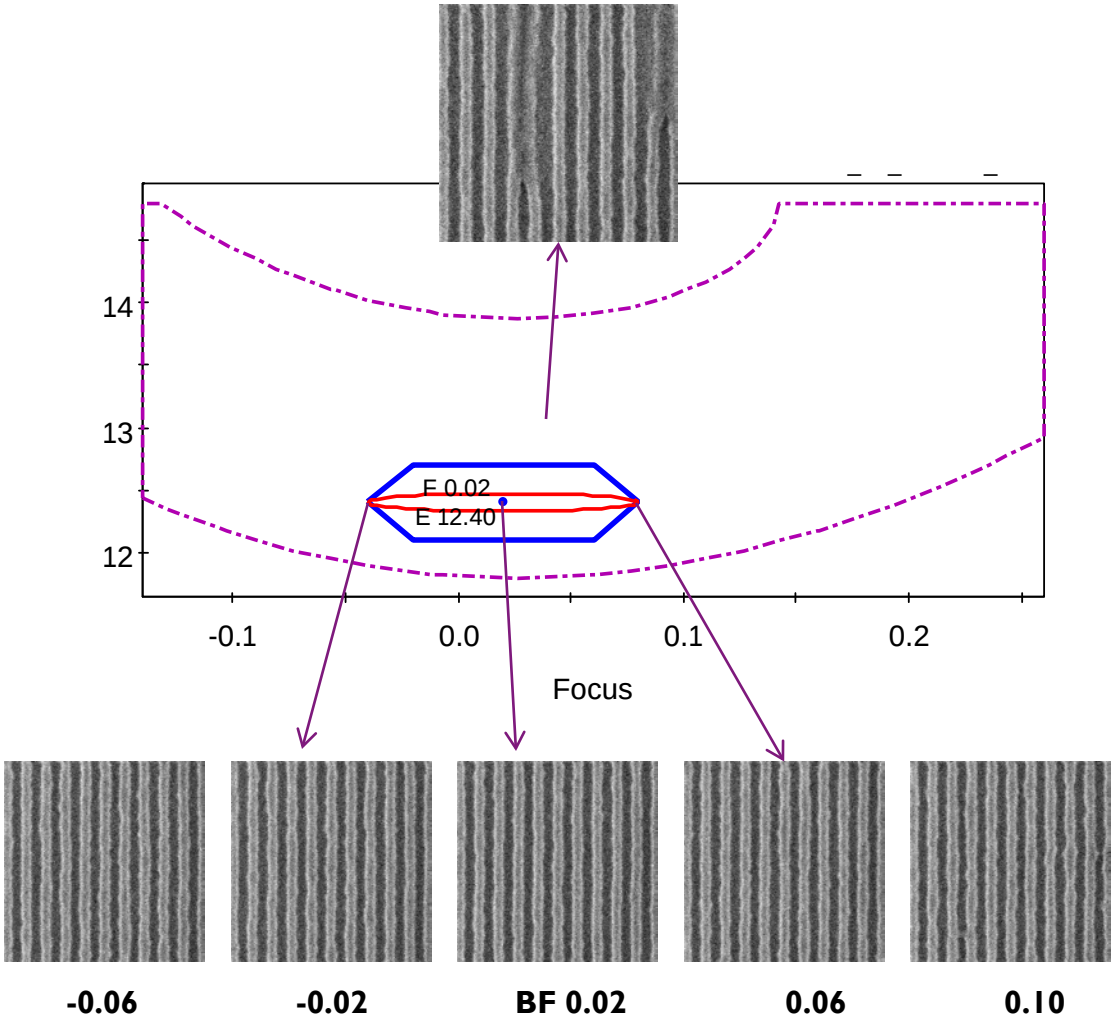
PROCESS WINDOW ON 22NM LS DIPOLE EXPOSURE RESIST D



Pattern collapse is limiting the Process window at 22nm HP

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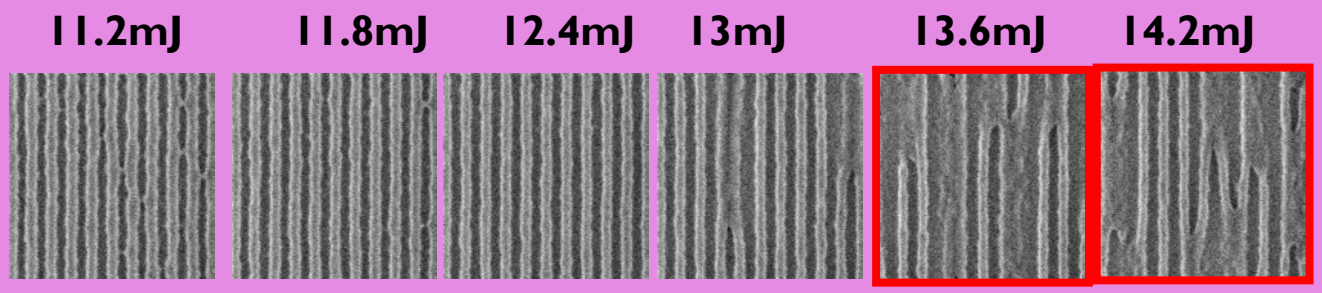
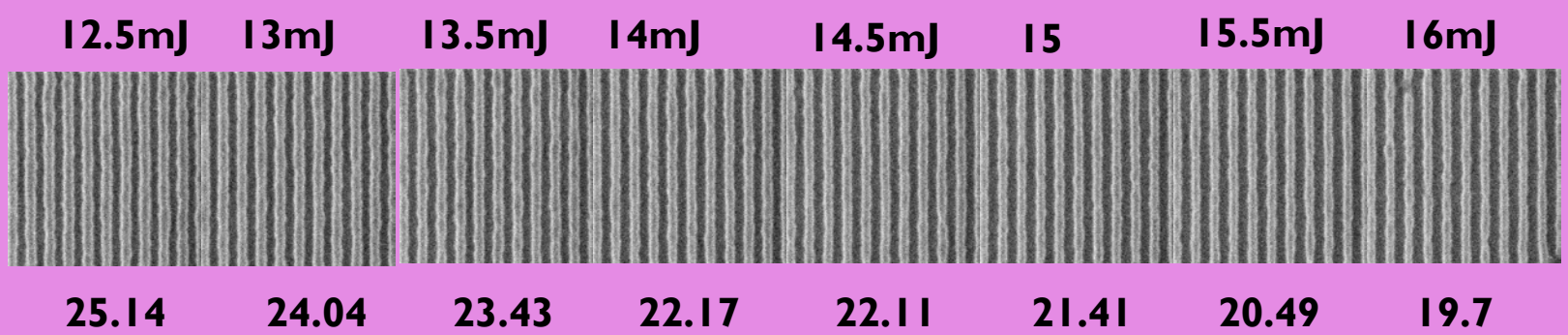
Application of FIRM
Pattern collapse margin on 22nm LS,
Resist D, 40nm FT

DI water



FIRM™Extreme



Aspect ratio increased from 1.7 to 2 by application of FIRM

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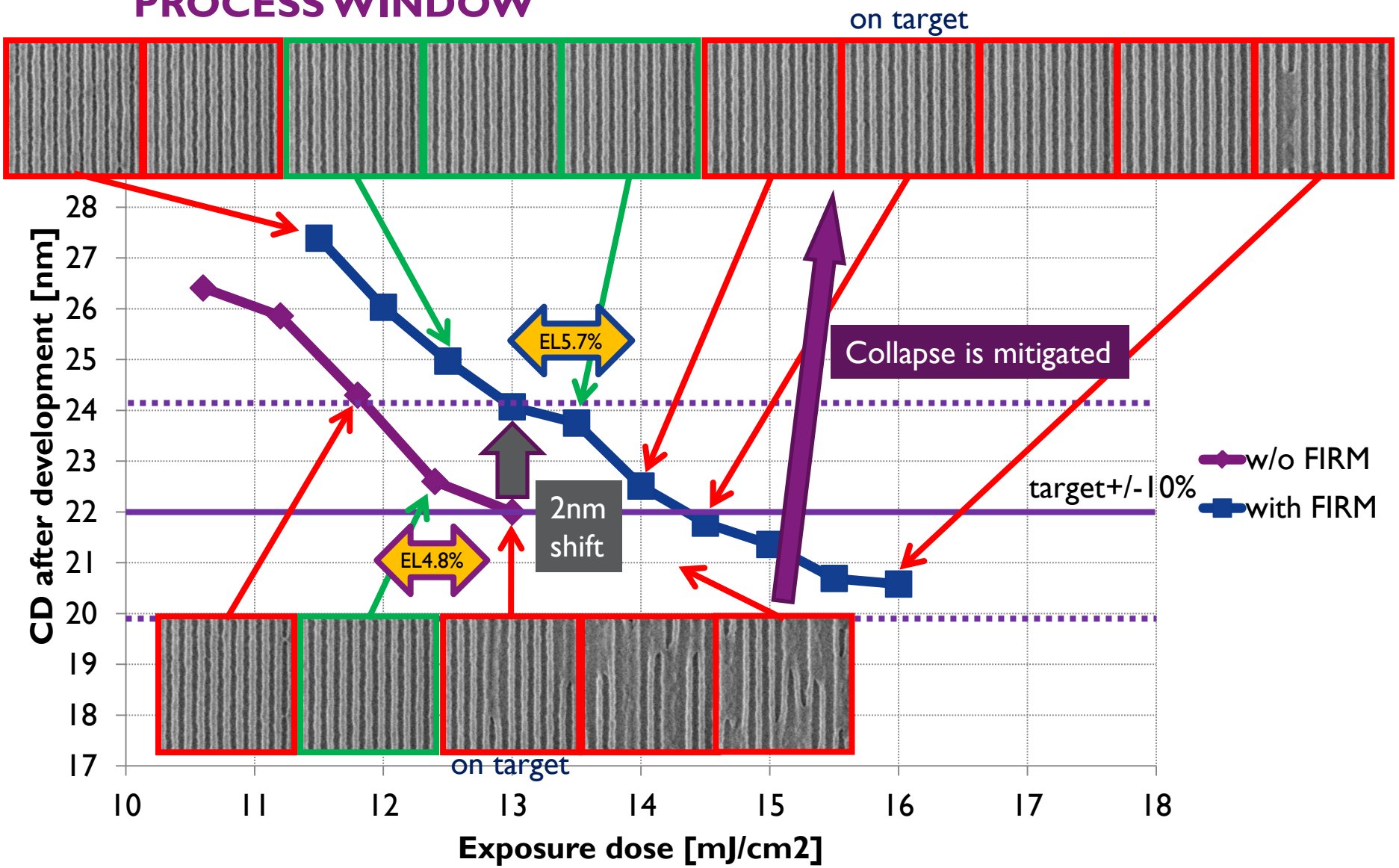
APPLICATION OF FIRM FOR 22NMHP

PROCESS WINDOW



FIRM rinse mitigates collapse but 2nm increase in CD

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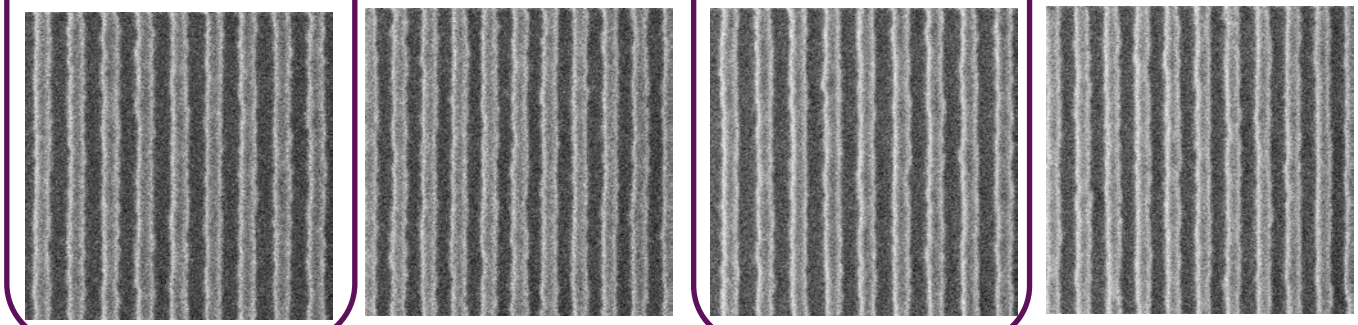
APPLICATION OF FIRM RINSE EFFECT ON LER AND PROCESS WINDOW

	DI-water rinse		Firm rinse	
CD	L25P50	L22P44	L25P50	L22P44
Dose to size	13.2mJ/cm2	13.3mJ/cm2	14.5mJ/cm2	14.6mJ/cm2
3 sigma LER	3.5nm	3.9nm	3.2nm	3.5nm
Max Exp latitude	19.4%	4.8%	20%	5.7%
Max DOF	240nm	120nm	200nm	120nm

NXE :3100
Resist D @40nm
E2stack AL412@ 20nm

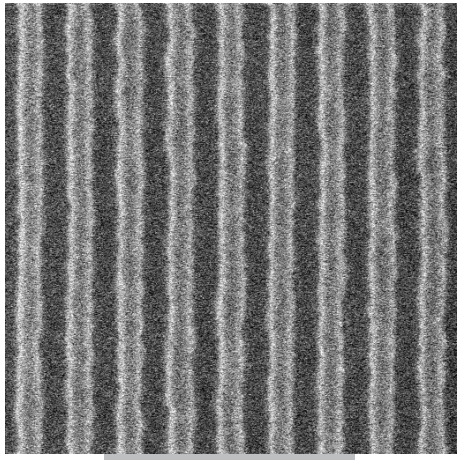


25nm LS performance is meeting the specification for sensitivity and latitudes and is very close to the LER target. Small improvement in latitude with Firm rinse but 9% reduction in LER.

NXE:3100 ULTIMATE RESOLUTION

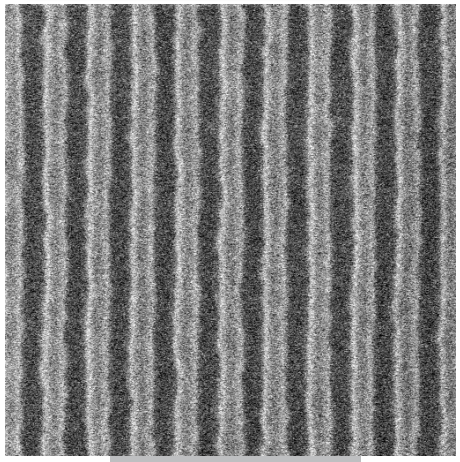
DIPOLE ILLUMINATION, 40NM RESIST D ON UL

25nm LS



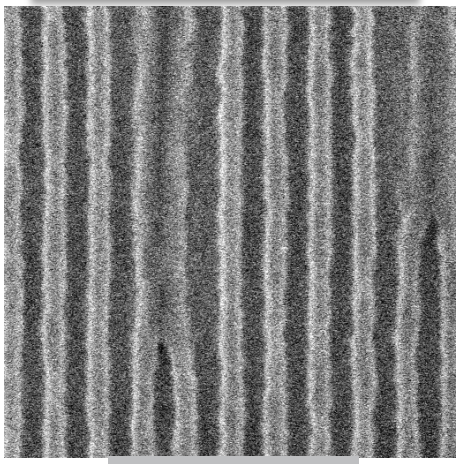
13mJ/cm2
CD=24.7nm
3.5nm LER

22nm LS



12.4mJ/cm2
CD=22.6nm
3.9nm LER

22nm LS
at DTS



13mJ/cm2
CD=22.0nm

Ultimate resolution is limited to 22nm because of pattern collapse

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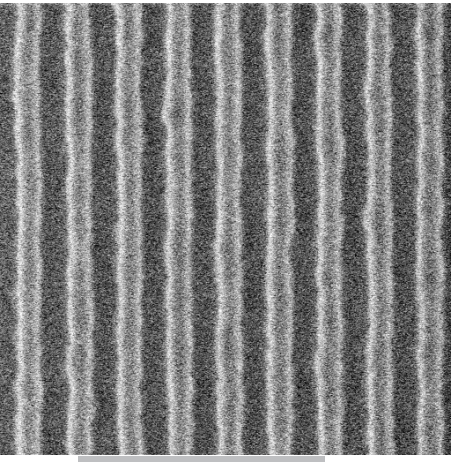
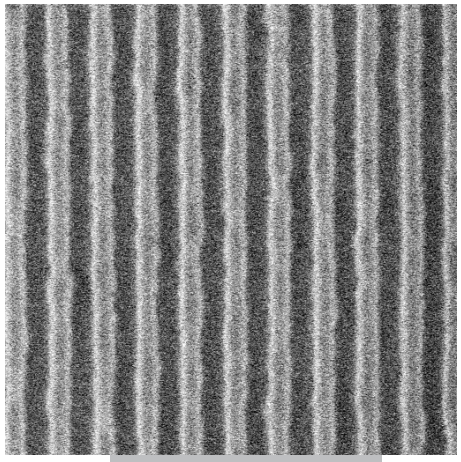
NXE:3100 ULTIMATE RESOLUTION WITH FIRM
DIPOLE ILLUMINATION, 40NM RESIST D ON STD UL

25nm LS



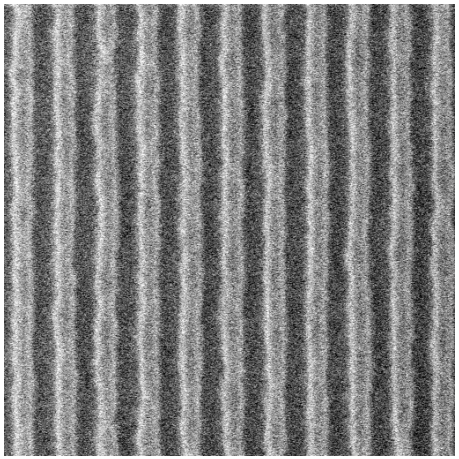
14.5mJ/cm2
CD=24.8
3.2nm LER

22nm LS



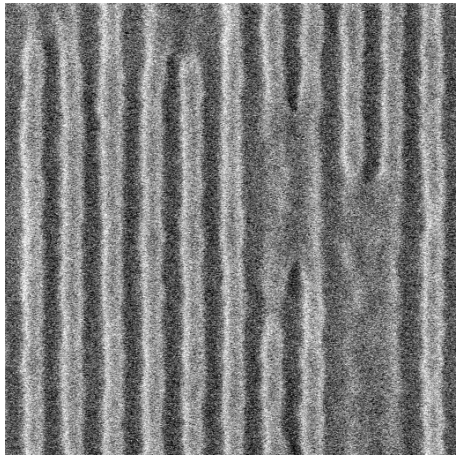
14.5mJ/cm2
CD=21.78nm
3.5nm LER

21nm LS



14 mJ/cm2
CD=21.6nm

20nm LS



14 mJ/cm2
CD=20.6nm

The application of FIRM rinse improves the Ultimate resolution down to 21nm LS for resist D
Collapse is still the resolution limiting factor

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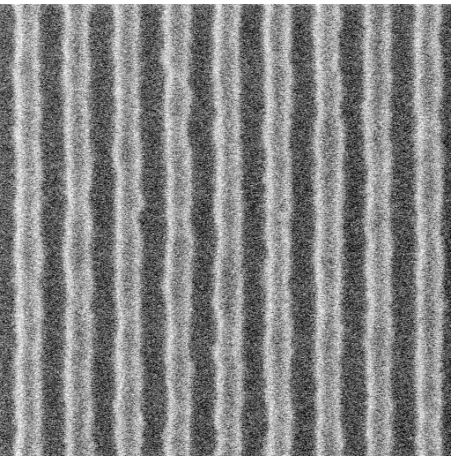
NXE:3100 ULTIMATE RESOLUTION

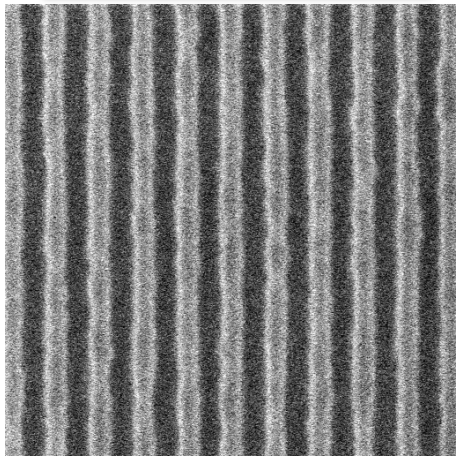
DIPOLE ILLUMINATION, 50NM RESIST C ON STD UL WITH FIRM

25nm LS



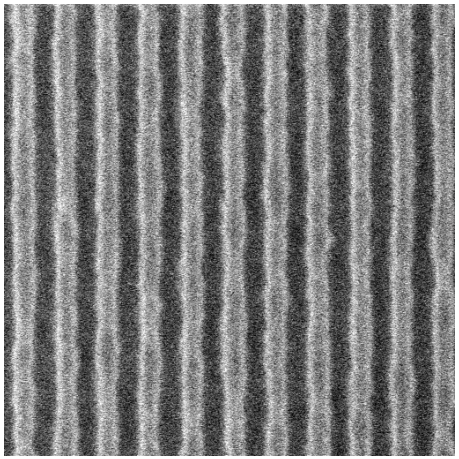
12mJ/cm2
CD=25.2nm
3.6nm LER

22nm LS



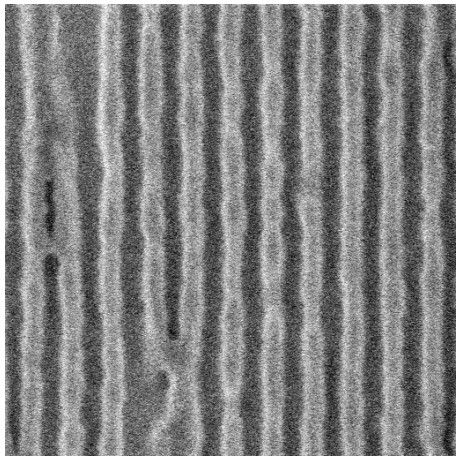
12.5mJ/cm2
CD=21.7nm
4.0nm LER

21nm LS



12.0mJ/cm2
CD=21.4nm

20nm LS



12.0mJ/cm2
CD=20nm

*Ultimate resolution of resist C is **21nm** in 50nm resist thickness with FIRM rinse, corresponding to an aspect ratio of 2.5*

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SUMMARY/1

Resist performance on ADT

- EUV resists are steadily improving
  - Reasonable performance for 28nm LS and 30nm CH on ADT in terms of process windows, profiles, photospeed
  - Resolution of 25-26nm LS demonstrated in several resists on ADT
  - **LWR/LCDU** are still the main parameter not meeting target
- Promising resists identified for detailed benchmarking on NXE

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SUMMARY/II

Resist performance on NXE:3100

- Dipole illumination enables sub-22nm resolution
  - 21 nm resolution has been demonstrated in several resists
- Wide processing latitudes for 25nm LS
  - Initial target for sensitivity, dose and PW are met
  - LWR is still the key parameter which need improvement
- Surfactant rinse has shown to be effective to reduce pattern collapse , reduce the LWR and extend the ultimate resolution

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