JSR SEMICONDUCTOR MATERIALS LABORATORY

Novel EUV resist development for 13nm half pitch

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Contents

- *Requirement for EUV resist*
- *JSR strategy for CAR improvement*
  - *High Tg Resin*
  - *Short acid diffusion PAG*
- *Metal resist development*
- *Summary*

When Will EUV Come in Industry?

MPU Fins and Flash Lines

Year		'14	'16	'18	'20
hp ~15nm	imm QP				
15 ~11nm	DSA, EUV DP, Imprint				
11 ~8nm	DSA, EUV DP, Imprint, ML2, High NA EUV				
8nm~	EUV DP, High NA EUV, DSA extension, Imprint, ML2				

DRAM Contact

Reference : ITRS 2013

Year		'14	'16	'18	'20
hp ~36nm	imm DP				
36 ~27nm	Imm TP/QP, EUV SP, DSA				
27 ~18nm	EUV SP, ML2, imprint, DSA, imm 4+exposure				
18nm~	High NA EUV, EUV DP, DSA, ML2, imprint				

- ✓ ***EUV will be ready for mass production on 2017-18?***
- ✓ ***15-11nmhp@LS, 36-18nmhp@CH resolution will be required for EUV resist.***

EUV resist application for N7

Imec advanced logic lithography roadmap

Early Prediction	2015-2016	2017-2018	2019-…
	10nm	7nm	5nm
Fin pitch (nm)	30-32	21-24	14-16
Gate pitch (nm)	50-64	40-45	22-32
Contact pitch (nm)	50-64	40-45	22-32
Metal pitch (nm)	40-45	28-32	20-22

Reference : Alindam et al., Proc. SPIE 9422 -85 (2015)

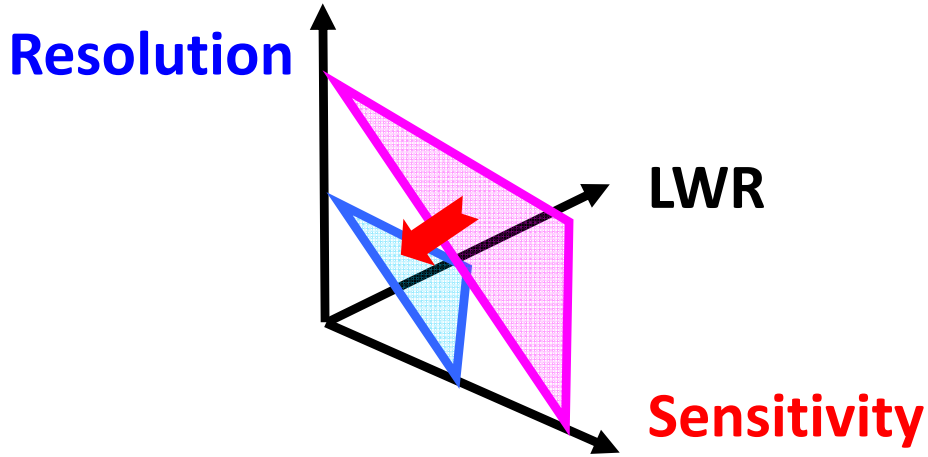
EUVL introduction at N7 technology

Layer	N7			
	Pitch	193i patterning scheme	EUV-BLK	EUV-Mx
Active/Fin	24	SAQP+LELE CUT		
Gate pattern	42	SADP + CUT		
M0A	42	LELE		
M0G	42	LELE		
V_0		LE^4	EUV SE	EUV SE
M-Int	28-32	SAQP +LE^3 BLOCK	SADP +EUV SE BLOCK	NA
V-int	28-32	LE^4	EUV SE	NA
M_1	40-45	SADP +LE^3 BLOCK	SAQP +EUV SE BLOCK	EUV SE
V_1		LE^4	EUV SE	EUV SE
M2	28-32	SAQP +LE^3 BLOCK	SAQP +EUV SE BLOCK	EUV SE
V_2		LELELE	EUV SE	EUV SE
Mx	28-32	SAQP +LE^3 BLOCK	SAQP +EUV SE BLOCK	EUV SE
Vx		LELELE	EUV SE	EUV SE
My		SADP+BLOCK		
Vy		LELE		

✓ ***The performance of EUV resist on actual application for N7 is being investigated.***

Strategy for CAR Improvement

Requirements for EUV resist

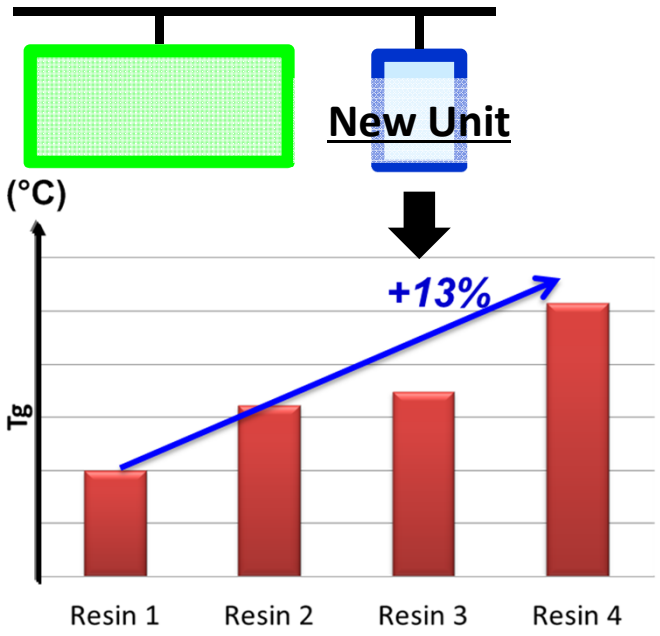


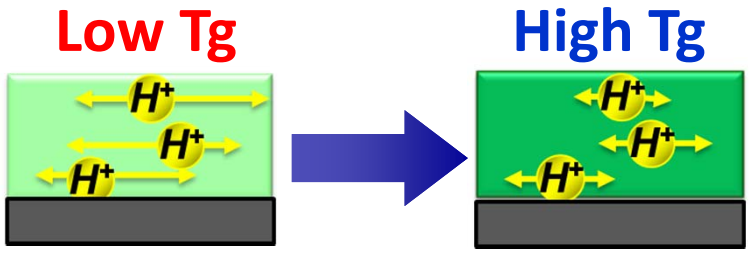
- ✓ Low Outgassing
- ✓ Suppression of OoB influence
- ✓ Defectivity
- ✓ etc…

JSR Strategy for CAR improvement

- ✓ Resin : High Tg resins for acid diffusion control
- ✓ PAG : Short acid diffusion PAG

Acid Diffusion Control by Resin





Berkeley MET, NA0.30

	22 nm HP	20 nm HP	Z-factor
Resin 1			2.93E-08
Resin 2			2.17E-08
Resin 3			2.04E-08
Resin 4			1.74E-08

Z-factor = (Resolution)^3 X (LER)^2 X (Sensitivity)

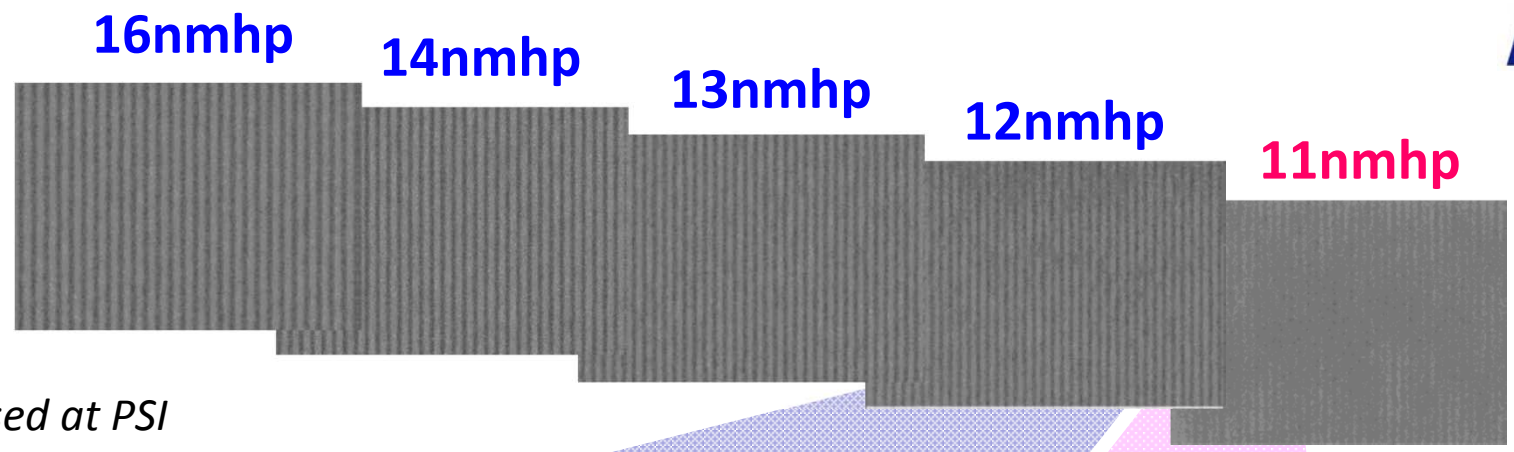
T. Wallow et. Al. SPIE 2008, 69211F

#Detail was published in SPIE 2014 (9048-48)

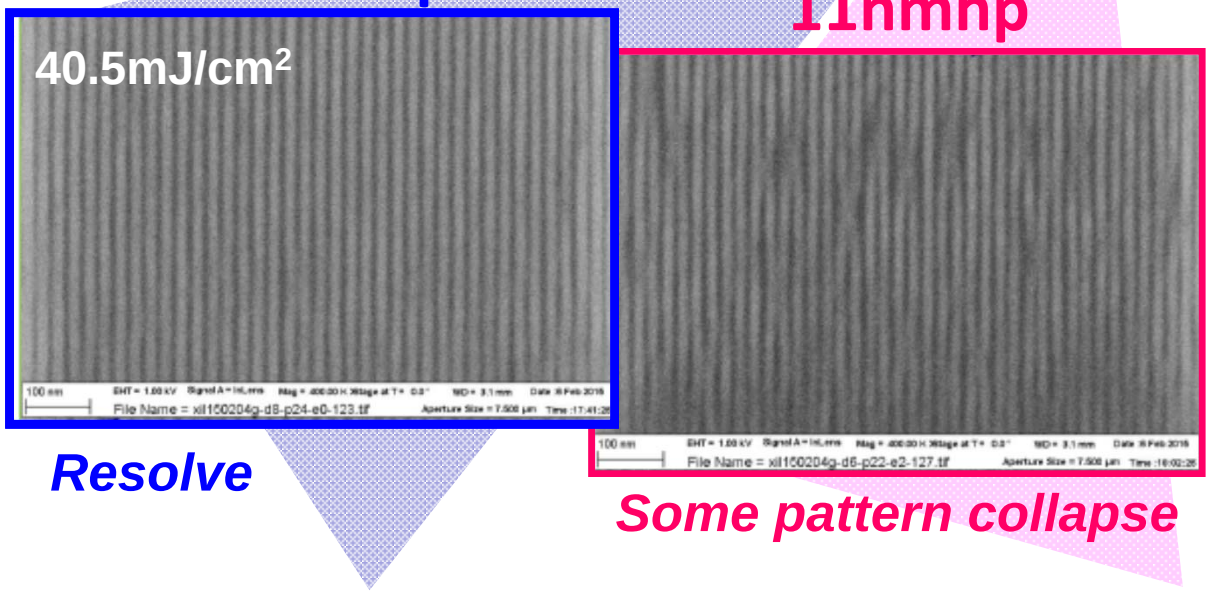
- ✓ ***Acid diffusion control by higher Tg resin is effective to improve resolution and Z-factor.***

Ultimate Resolution of New JSR CAR

ASML

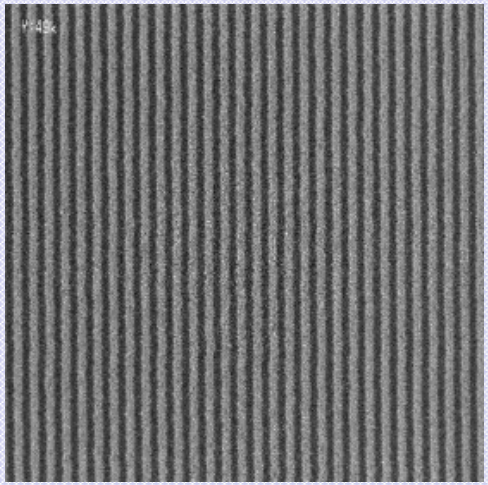
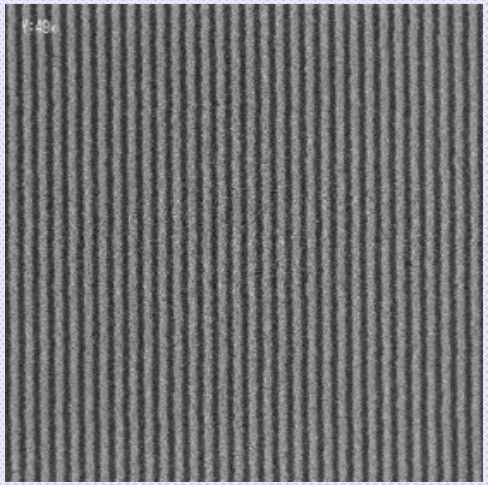
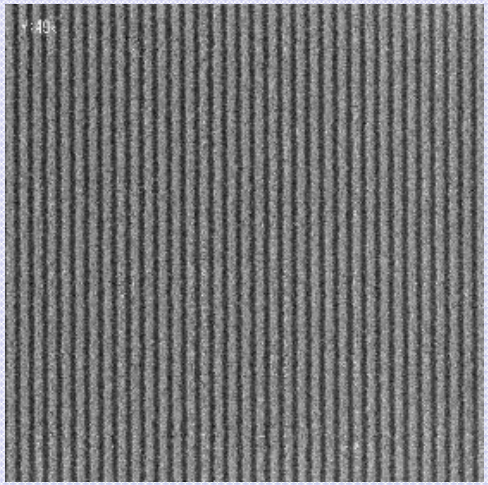


Exposed at PSI



✓ *12nmHP is well resolved by JSR New CAR resist*

Resolution of new CAR@NXE3300

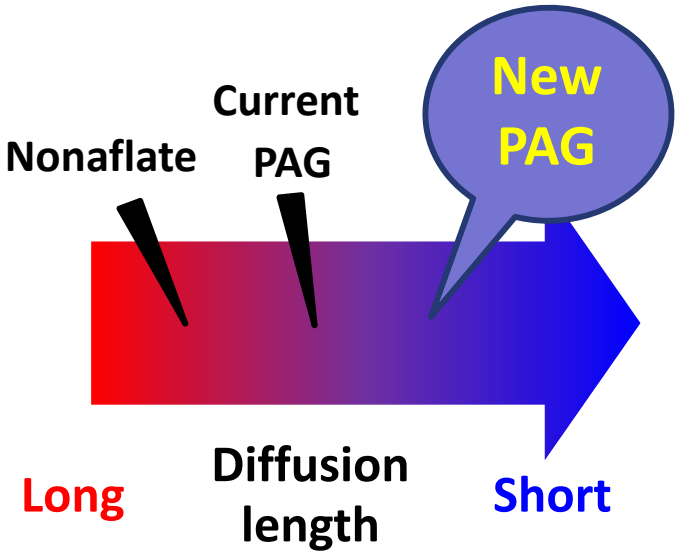
15nmhp LS	14nmhp LS	13nmhp LS
41.6mJ/cm^2	40.0mJ/cm^2	36.8mJ/cm^2
		
Resolved	Resolved	Resolved

Exposed at NXE3300

- ✓ *JSR New CAR resist well resolves 13nmHP on NXE3300.*
- ✓ *However the improvement of sensitivity is required*

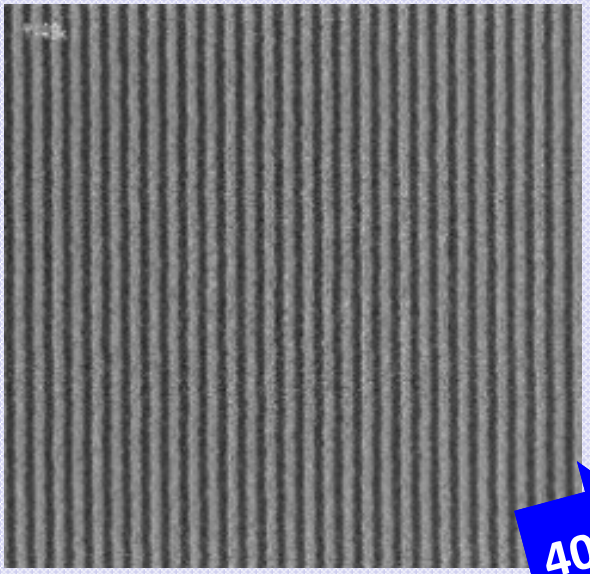
New PAG Development for L/S

PAG properties



@15nmhp

Current PAG

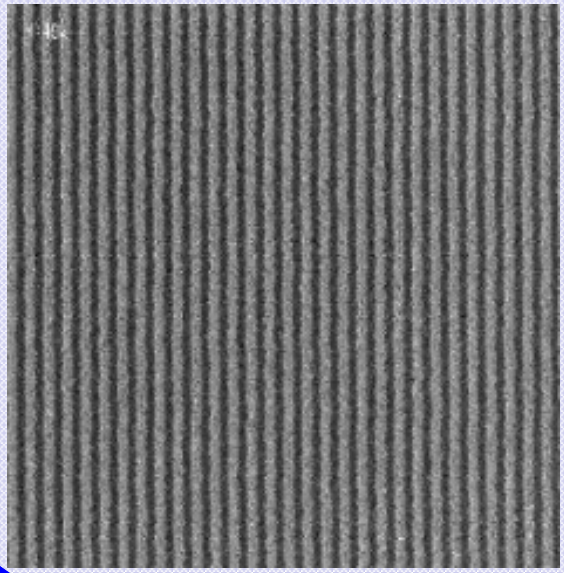


DtS: 41.6mJ/cm²
LWR: 5.9nm

40%

10%

New PAG



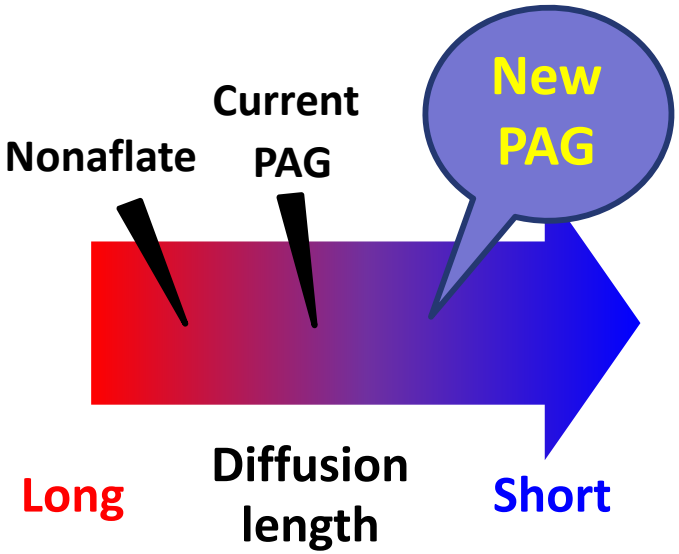
DtS: 25.2mJ/cm²
LWR: 5.3nm

Exposed at NXE3300

✓ ***The development of new PAG enables breakthrough performance.***

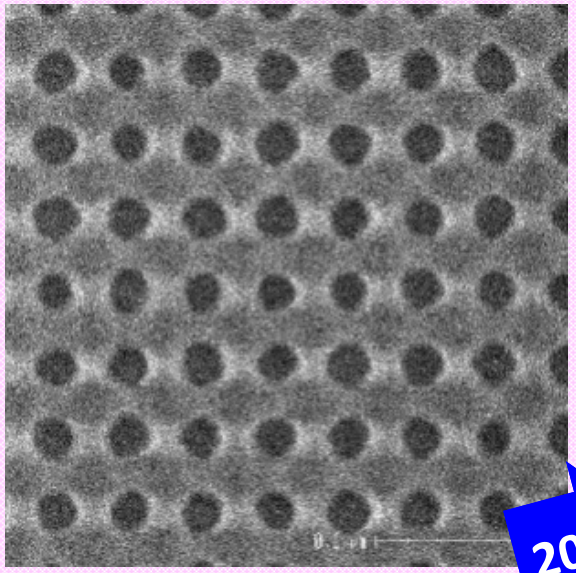
New PAG performance for C/H

PAG properties



@22nmhp

Current PAG

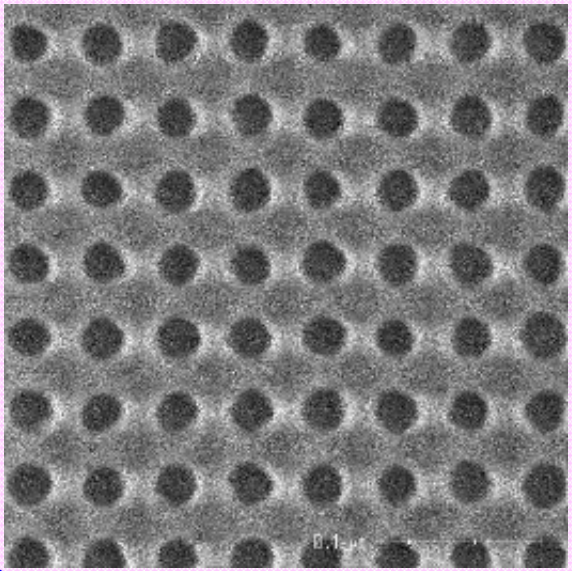


DtS: 29.2mJ/cm²
CDU: 4.2nm

20%

20%

New PAG

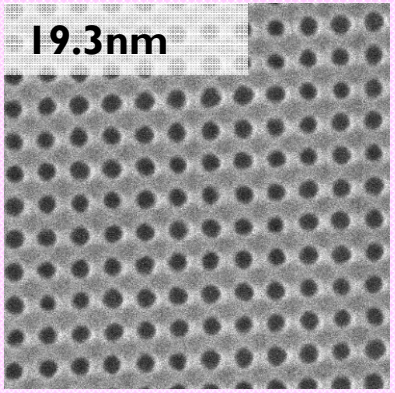
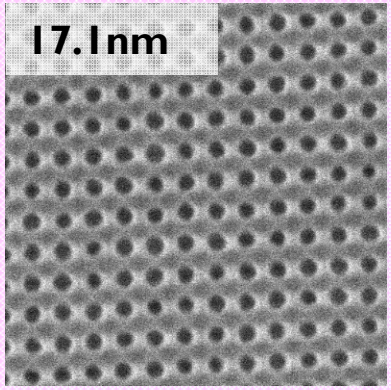
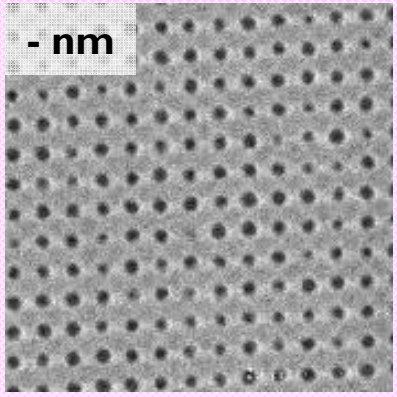
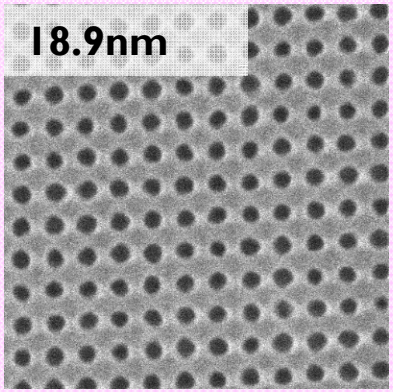
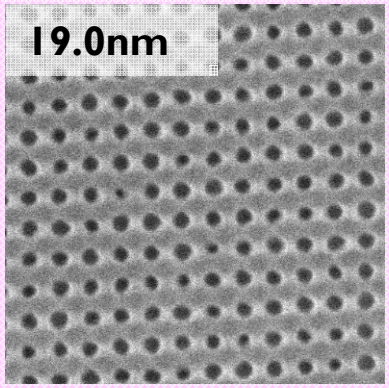
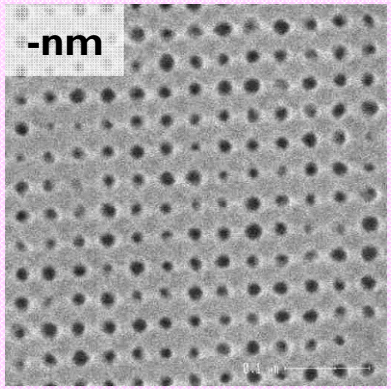


DtS: 23.6mJ/cm²
CDU: 3.2nm

Exposed at NXE3300

✓ ***The resist performance at CH application was also improved by applying similar strategy to LS application.***

C/H resolution of new CAR@NXE3300

	19nmhp CH	18nmhp CH	17nmhp CH
Sample-A @80mJ			
	Resolved	*Resolved*	*Not resolved*
Sample-B @36mJ			
	Resolved	*Some missing CH*	*Not resolved*

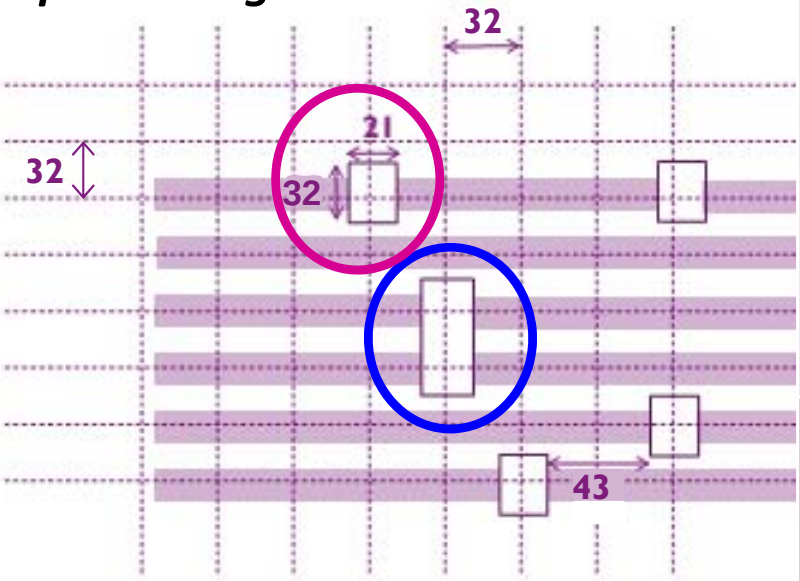
Exposed at NXE3300

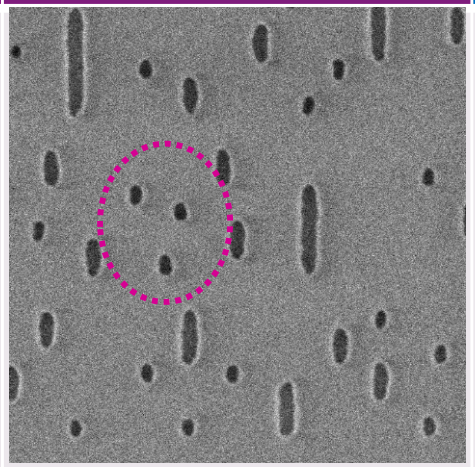
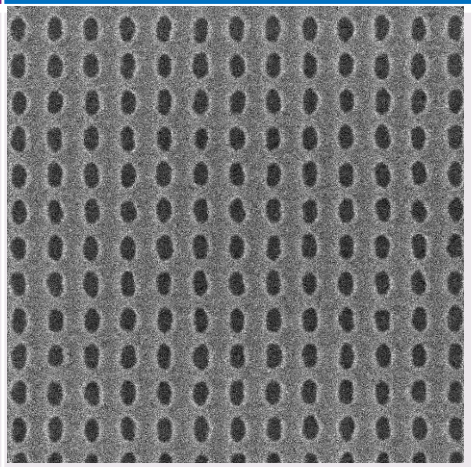
✓ *JSR CAR resist can resolve 18~19nmhp on NXE3300*

Printing result at Block mask layer for metal patterning

MASK DESIGN

@IMEC N7 block mask for metal patterning



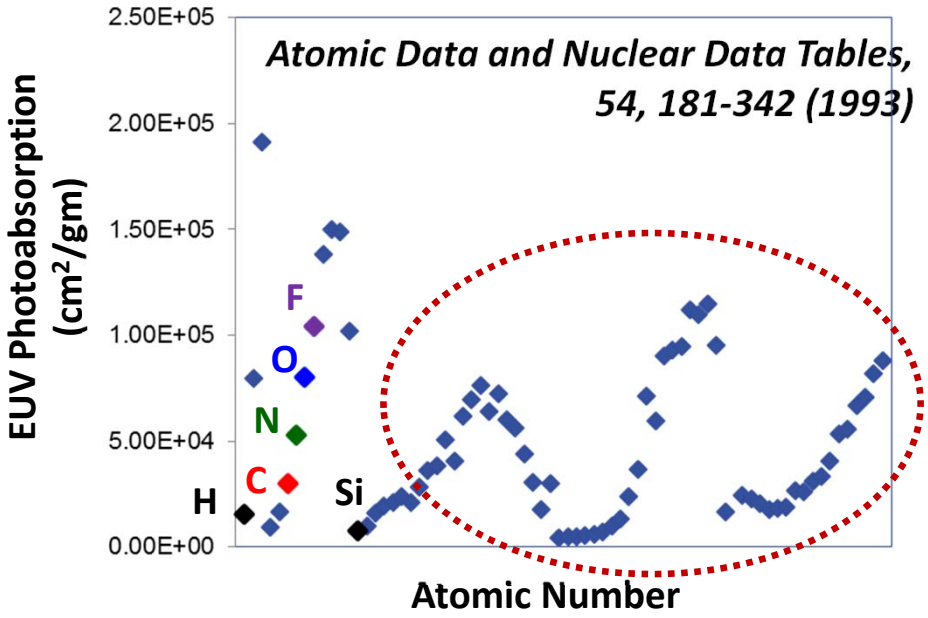
		21x32 rectangle	26x52 rectangle
			
CDx	DtS	23.9 mJ/cm²	21.3 mJ/cm²
	LCDU(3σ)	-	2.50 nm
	EL	18.2 %	21.6 %
	DOF@10%EL	110 nm	220 nm
	Max DOF	140 nm	220 nm

Exposed at NXE3300

✓ ***Improvement of resist performance was observed for not only simple CH pattern but also actual application pattern.***

Metal resist

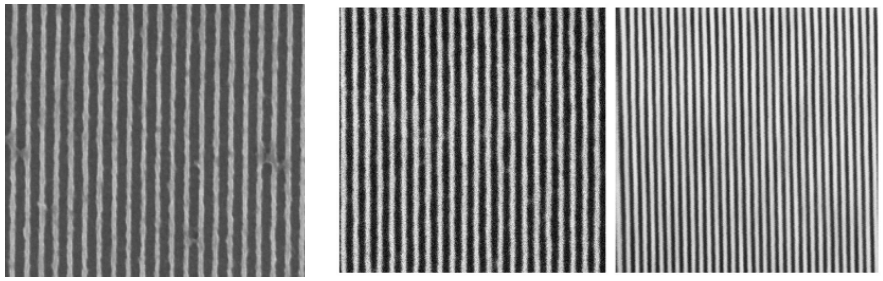
EUV Photoabsorption Cross Section



Potential Benefit of Metal resist

- High sensitivity
- High etching selectivity

Cornell **inpria**



26 nm lines 4.2mJ/cm² ***12 nmhp*** ***8 nmhp***

Trikeriotis et al., Proc. SPIE 8322 83220U-3 (2012)
Ekinci et al., Proc. SPIE 2013, 8679 867910-2 (2013)

✓ ***JSR has been investigating metal species as Sensitizer or Metal resists.***

Current improvement results of JSR

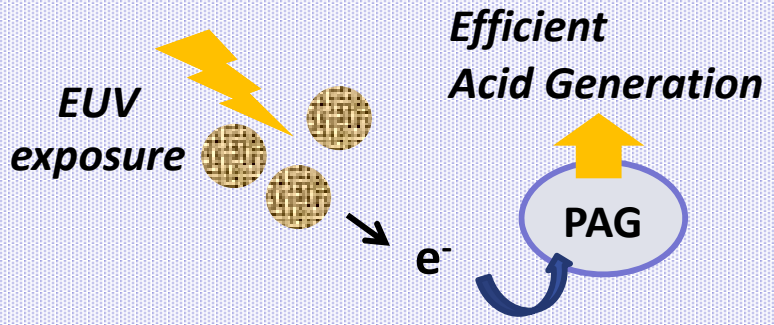
SEMATECH

Conventional CAR	CAR + Metal sensitizer
@18nmhp	
54.2mJ/cm²	45.8mJ/cm²
LWR:2.7nm	LWR:2.8nm

16% Improvement

Exposed at Berkeley MET

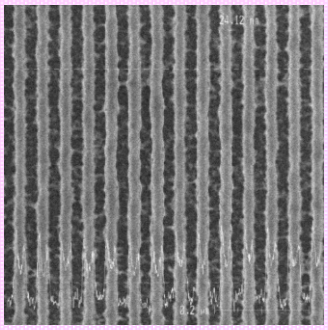
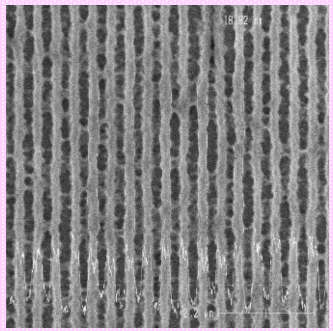
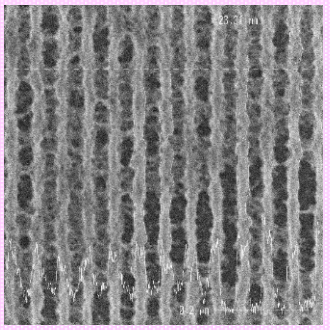
JSR new sensitizer improves EUV resist sensitivity with keeping resolution and roughness at sub-20nmhp.



imec

JSR started to development of Metal resist using NXE3300.

Our system also have potential to resolve fine pattern with excellent sensitivity.

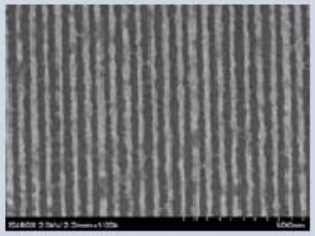
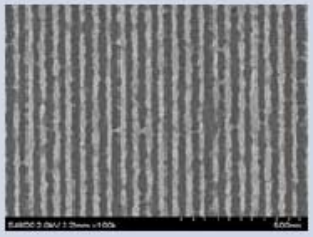
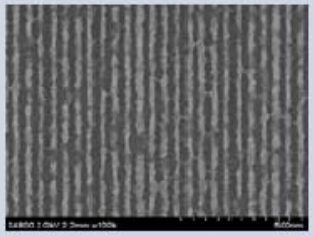
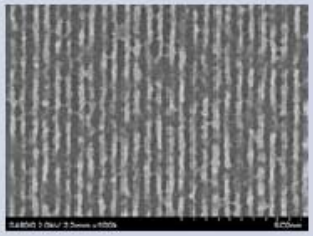
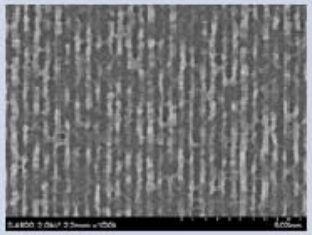
Metal resist-A		Metal resist-B
		
24nmhp LS	19nmhp LS	27nmhp LS
77.6mJ/cm²	67.2mJ/cm²	7mJ/cm²

Exposed at NXE3300

2016 SPIE

SPIE Advanced Lithography 9776-3 Feb. 22, 2016

Metal resist smaller CD demonstrated.

Dose	28nmLS	26nmLS	24nmLS	22nmLS	20nmLS
6.0 mJ					

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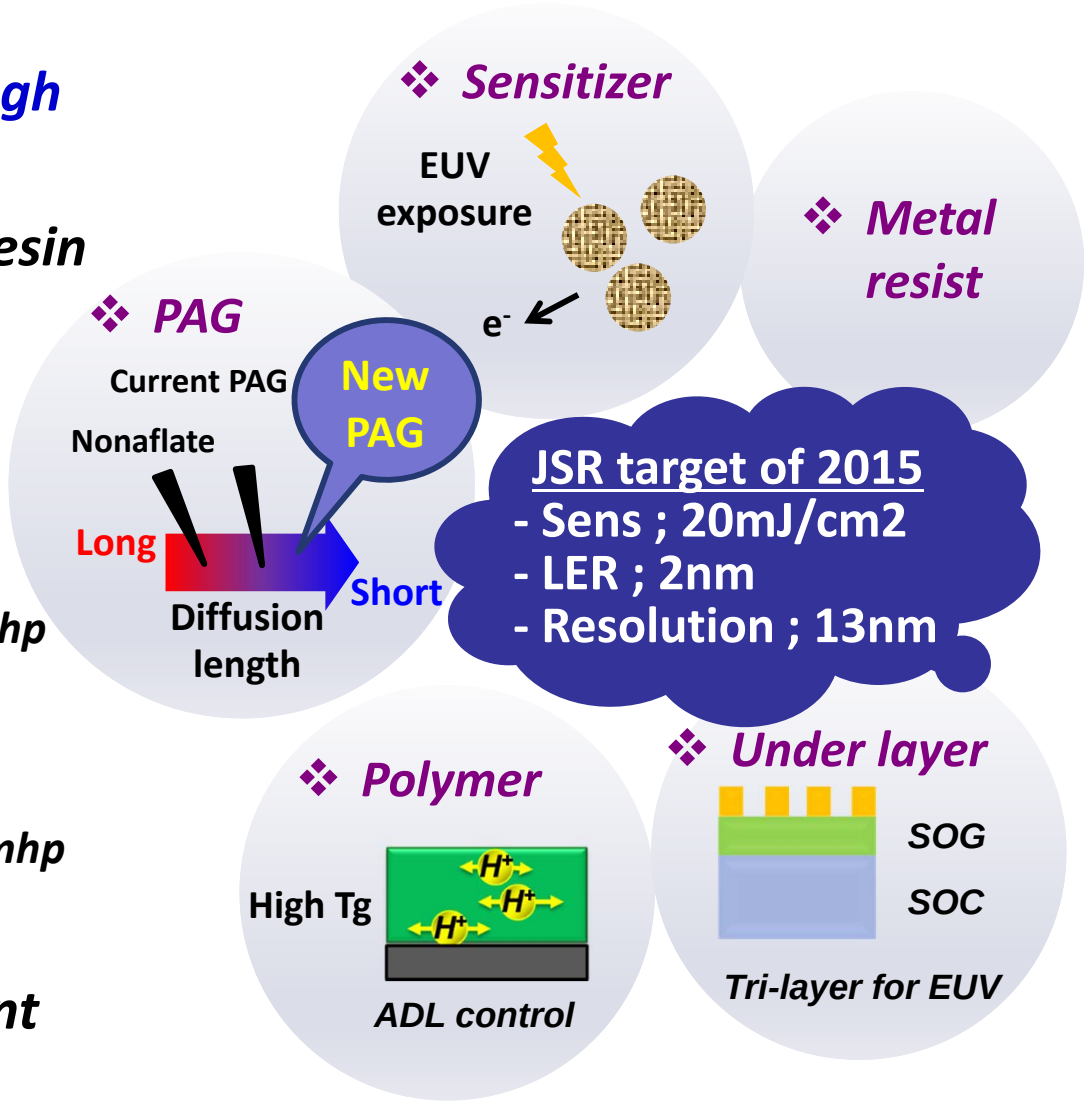
[a] JSR Corporation, [b] Cornell University

Summary

- ✓ ***Material development for breakthrough CAR performance***
  - ***Acid diffusion control by high Tg resin & short acid diffusion PAG***
- ✓ ***Current status of JSR CAR@NXE3300***
  - ***LS***
    - ***13nmhp line resolution***
    - ***DtS: 25.2mJ/cm2, LWR 5.3nm@15nmhp***
  - ***CH***
    - ***18nmhp hole resolution***
    - ***Dts: 23.6mJ/cm2, CDU 3.23nm@22nmhp***
- ✓ ***New metal resist development***
  - ***Has a potential to achieve excellent sensitivity at fine pattern***



Acknowledgement

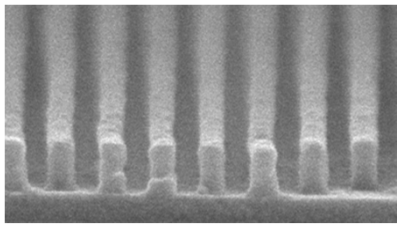
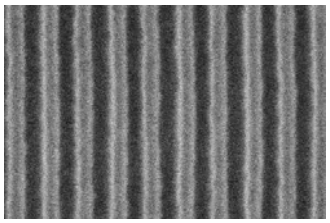
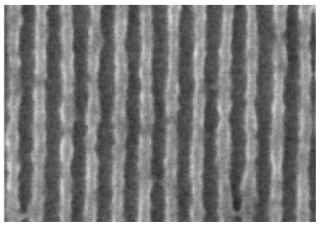
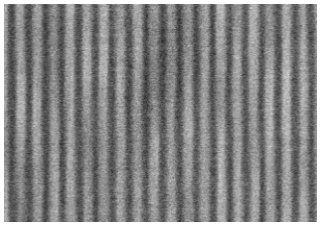
The authors gratefully thank to,

imec *for the close collaboration and discussion*

ASML *for the NXE3300 exposure and valuable discussion*

SEMATECH *for the exposure support on MET*

Thank you for your attention !!

2007	*2008*	*2010*	*2015*
40 nm LS, ArFi	*26 nm LS, ArFi DP*	*19 nm LS, EUV*	*12nm LS, EUV*
			

Materials Innovation

JSR