JSR Micro
MATERIALS INNOVATION

Novel EUV Resist Development for Sub-14nm Half Pitch

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JSR Micro Inc.

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  - *Strong acidity PAG*
- *JSR new high resolution CAR*
- *Sensitivity improvement by new sensitizer*
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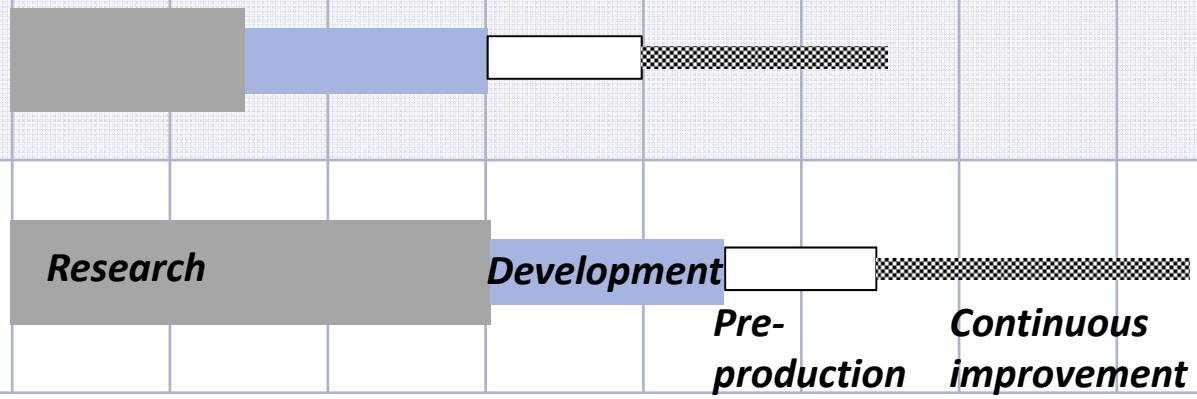
When Will EUV Come in Industry?

ITRS 2013 (MPU Fins and Flash Lines)

Year		'14	'16	'18	'20	'22	'24	'26	'28
Min hp after multi. patterning		17nm	14nm	12nm	12nm	11nm	8.4nm	6.7nm	5.3nm
20 - 30nm	ArF Imm DP								
15 - 20nm	ArF Imm QP								
11 - 15nm	ArF Imm QP, DSA, EUV DP, Imprint								
8 - 11nm	DSA, EUV DP, High NA EUV, Imprint, ML2								
- 8nm	DSA extension, EUV DP, High NA EUV. Imprint, ML2								



- ***EUV will be ready for mass production on 2017-18?***
- ***Sub-14nm resolution will be required for EUV resist.***

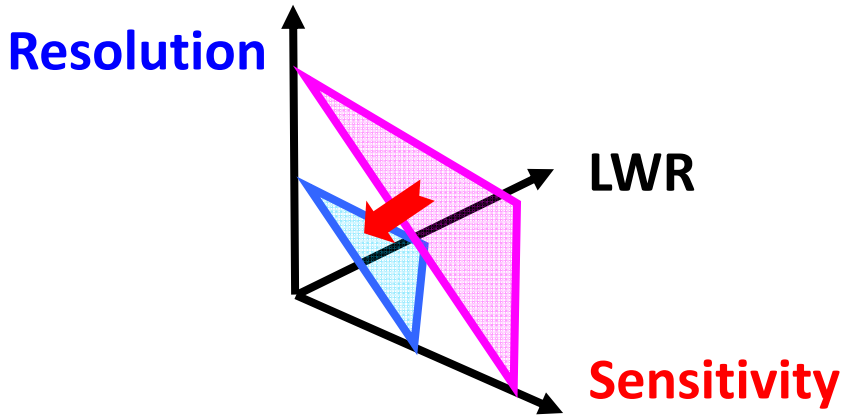
Requirements for EUV Resist

Source Power	Resist	
	Requirements	Appropriate Platforms
Low	✓ Super high sensitivity	Super sensitive novel resist
Middle	✓ RLS balance ✓ Defectivity control	CAR extension
High	✓ RL improvement ✓ Defectivity control	CAR extension
	✓ Super high resolution ✓ Super low LWR/LER ✓ Defectivity control	Super smooth Non CAR Resist

- ***Requirement and platform depend on source power.***
- ***In any case, Resolution and Sensitivity are key requirements.***

Strategy for Resolution & Sensitivity Improvement

Requirements for EUV resist

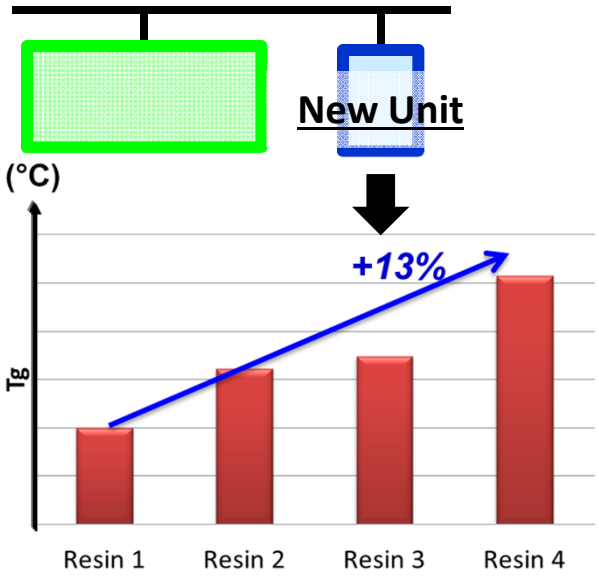


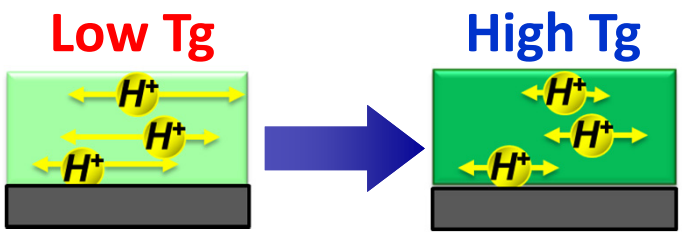
- ✓ Low Outgassing
- ✓ Suppression of OOB influence
- ✓ Defectivity
- ✓ etc…

JSR Strategy for Resolution & Sensitivity improvement

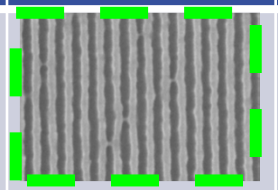
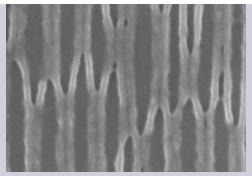
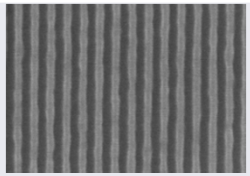
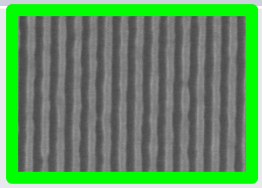
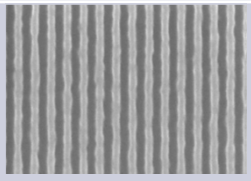
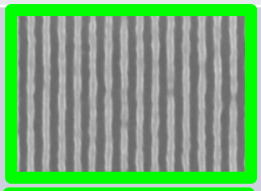
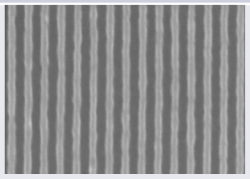
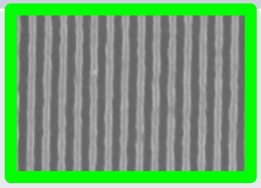
Item	Strategy
Resin	High Tg resin for acid diffusion control
PAG	New short diffusion length and strong acidity PAG
Additive	New sensitizer for high EUV photoabsorption

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)

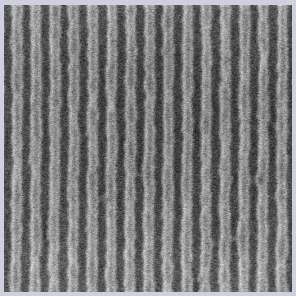
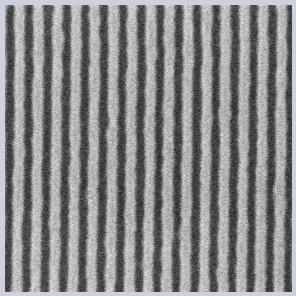
T. Wallow et. Al. SPIE 2008, 69211F

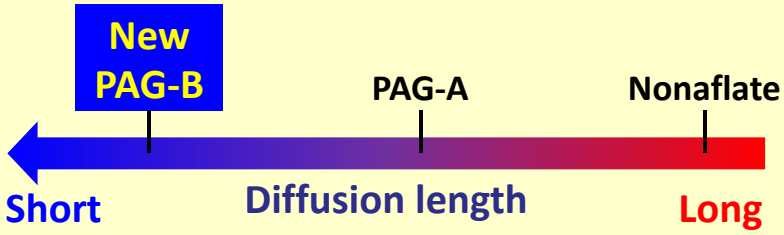
- ***Acid diffusion control by higher Tg resin is effective approach for improving resolution and Z-factor.***

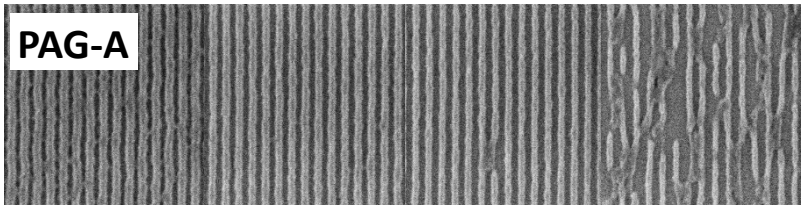
#Detail was published at SPIE 2014 (9048-48)

PAG Development (Diffusion length)

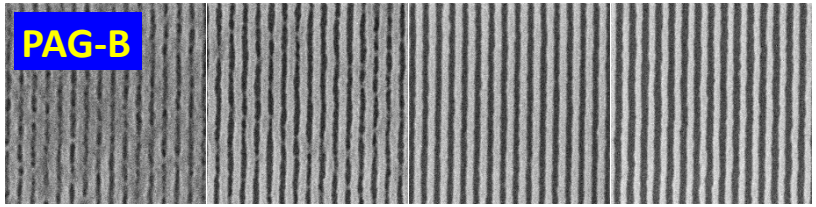
Albany MET, Quadrupole (0.36/0.93)

PAG	PAG-A (Ref)	PAG-B (New PAG)
Image 22nm HP		
Sensitivity (mJ/cm^2)	21.0	23.4
LWR (nm)	4.7	3.8
Min CD (nm)	22.7	<19.0





CD	22.7
LWR	4.7



CD	21.6	19.0
LWR	3.8	3.4

- *Acid diffusion length is one of the important nobs.*
- *New short diffusion PAG enabled the breakthrough performance.*

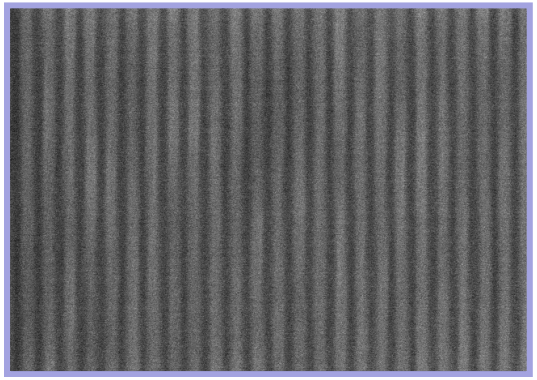
#Detail was published at SPIE 2015 (9422-24)

High Resolution CAR (BMET)

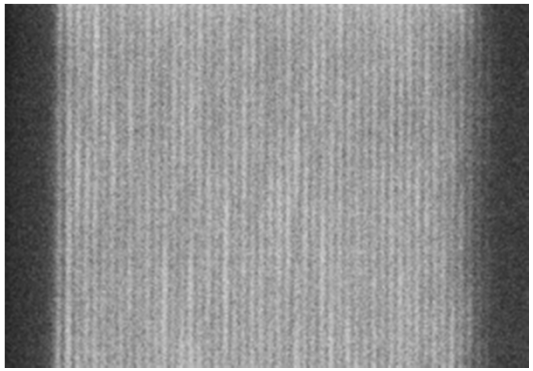
Short diffusion length PAG

HP	17nm	16nm	15nm	14nm	13nm
JSR CAR 35.5mJ/cm^2	17.4 nm	16.4 nm	15.4 nm	14.6 nm	13.7 nm

13nm HP



12nm HP



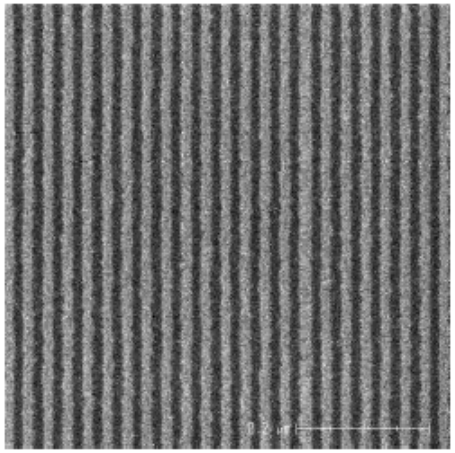
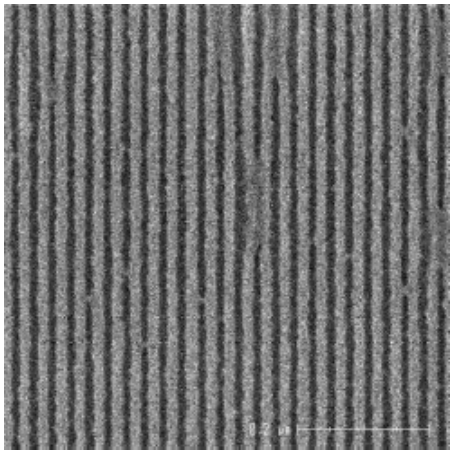
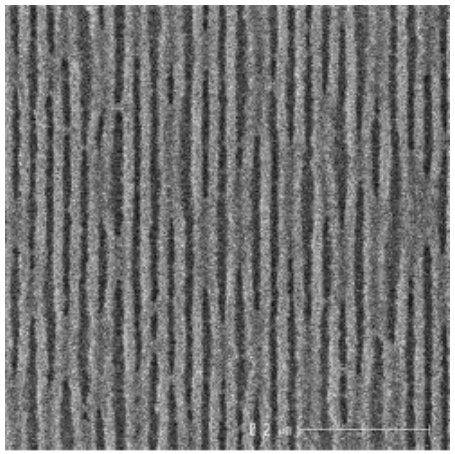
Berkeley MET, NA0.30

- ***13nm HP was resolved with short diffusion length PAG on BMET.***

High Resolution CAR on NXE3300

Ultimate resolution of JSR CAR

NXE3300, Dipole45, FT=30nm

15nmHP LS 37.5mJ/cm²	14nmHP LS 45mJ/cm²	13nmHP LS 45mJ/cm²
		
Resolved	Almost resolved	Many collapse

- ***Short diffusion PAG almost resolves 14nmHP on NXE3300.***

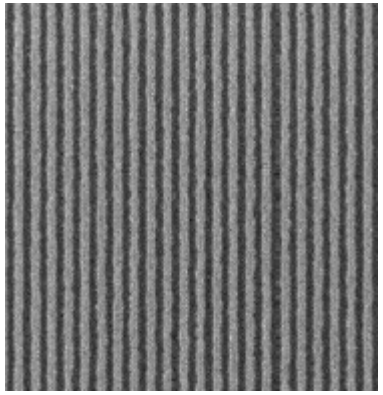
High Resolution CAR on NXE3300

16nmHP LS & 20nm Iso Trench performance

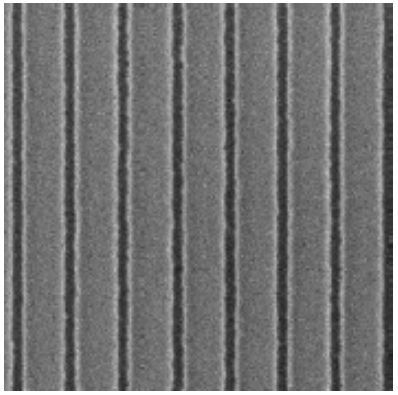
short diffusion length PAG

JSR CAR FT=30nm	Mask	Dose to Size (mJ/cm^2)	Min. CD (nm)	ELmax (%)	DOFmax (nm)	LWR (nm)
16nmHP LS	16L32P	44.8	14.8	18.6	100	4.3
20nm Iso Trench	22T112P	40.9	18.5	17.7	120	4.2

16nmHP LS



20nm IT



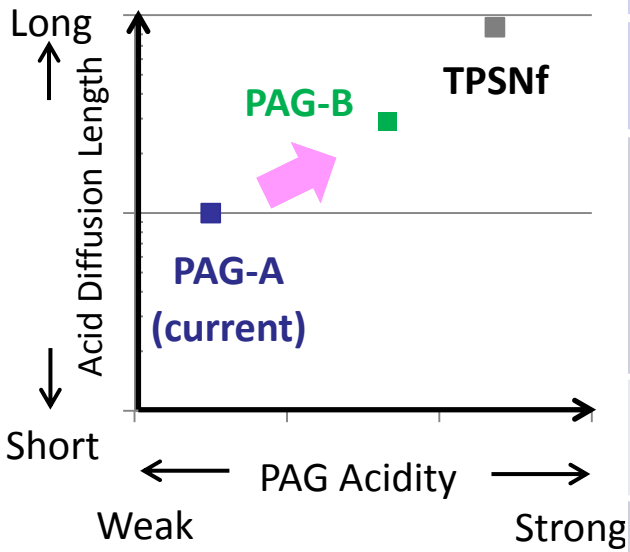
NXE3300, Dipole90

- ***JSR CAR resist showed good 16nmHP LS & 20nm IT process window.***

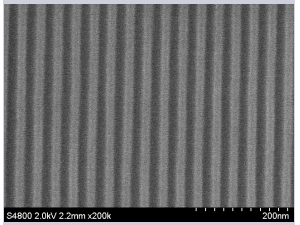
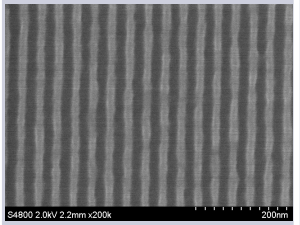
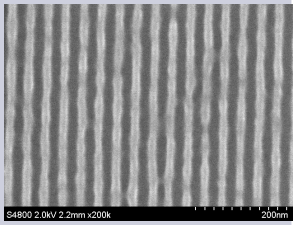
New PAG

PAG Development (Acidity)

PAG properties



Exposed at BMET, NA0.30

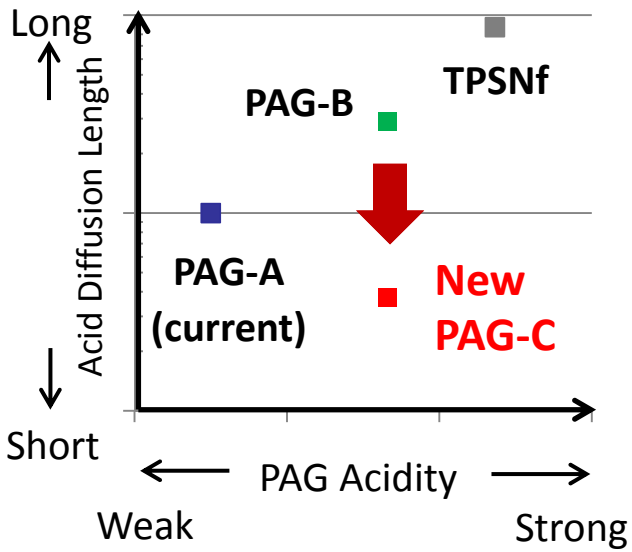
	Sample-A	Sample-B	Sample-C
PAG-A ratio (Weak)	100	50	0
PAG-B ratio (Strong)	0	50	100
Image			
Sen. (mJ/cm²) (20nmHP)	22.80	18.69	14.95
LWR (nm) (20nmHP)	4.10	5.41	6.72
Resolution (nm)	19-18	19	20

✓ ***Strong acidity PAG is effective for sensitivity improvement. But LWR and sensitivity are trade-off.***

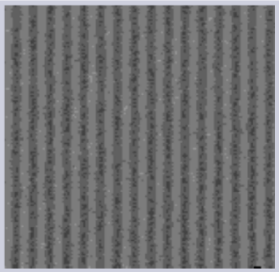
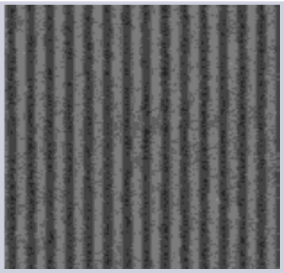
New PAG

PAG Development
(Diffusion length and Acidity)

PAG properties



Exposed at PSI

	PAG A	PAG C
PAG-A ratio (Weak)	100	0
PAG-C ratio (Strong & Low ADL)	0	100
Image		
Sen. (mJ/cm^2) (16nmHP)	36.1	19.4
LWR (nm) (16nmHP)	7.2	5.3

47%

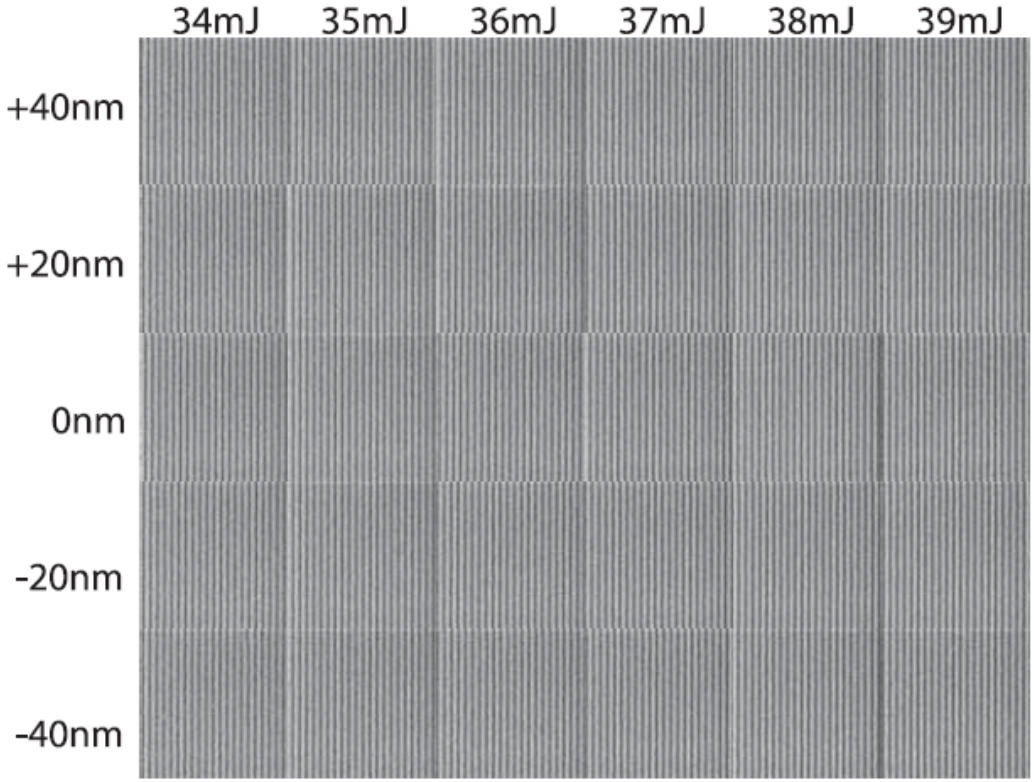
26%

✓ *JSR new short diffusion & high acidity PAG enables breakthrough performance*

JSR EUV Resist for 16nm HP

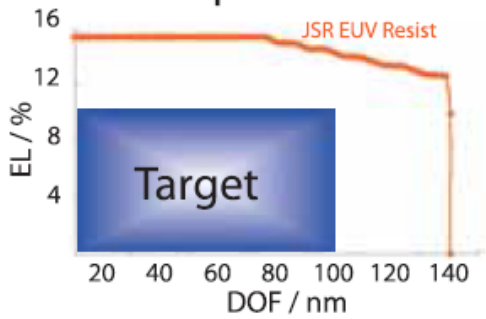
【JSR EUV Photoresist】

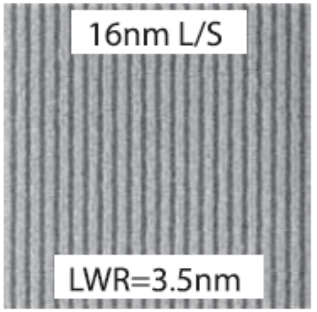
16nm L/S ED window



[Process Conditions]

- Substrate : Organic UL
- Resist FT : 35nm
- Exposure : NXE:3300B, NA0.33, Dipole45X



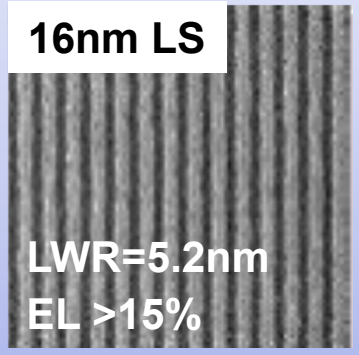


Exposure Courtesy of ASML and imec

✓ *JSR EUV photoresist showed certain process window at 16nmHP.*

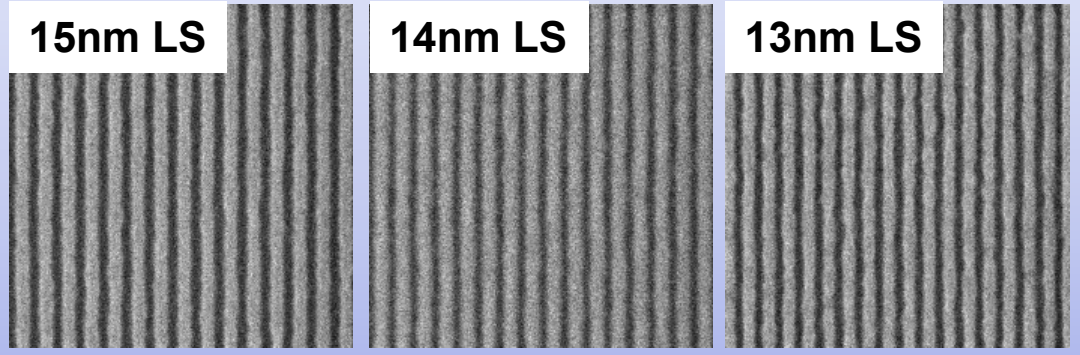
JSR High Resolution Resist

on NXE3300
Dipole90X



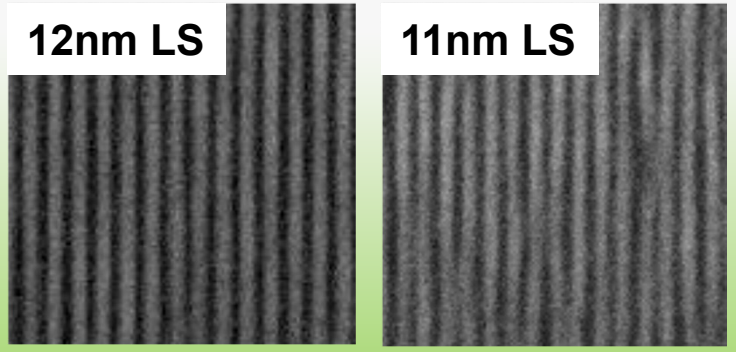
39.2mJ/cm^2

on NXE3300
Dipole45X



40.4mJ/cm^2 36.8mJ/cm^2 38.6mJ/cm^2

on PSI

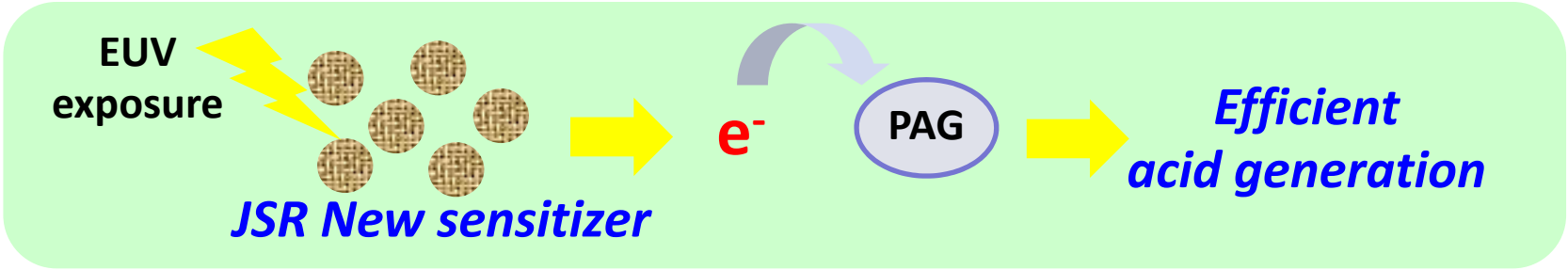


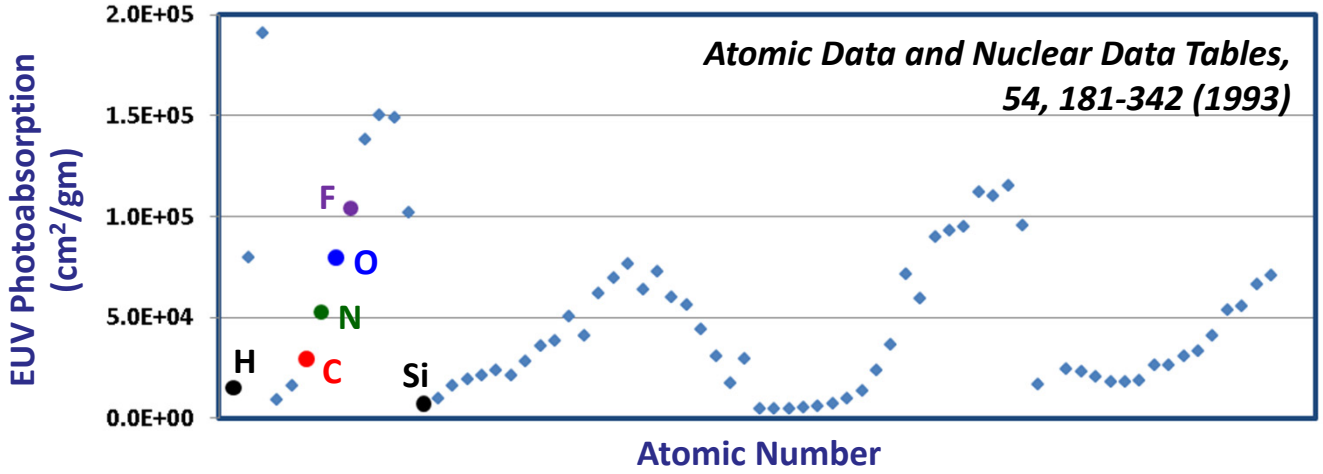
40.5mJ/cm^2 Resolve

33.6mJ/cm^2 Pattern collapse

✓ *13nm HP (NXE3300) and 12nm HP (PSI) resolution was achieved by JSR EUV photoresist.*

Concept of New Sensitizer

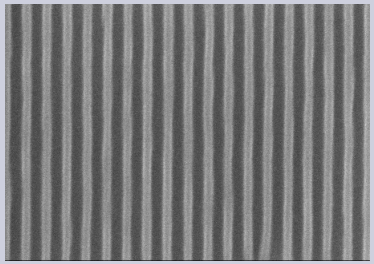
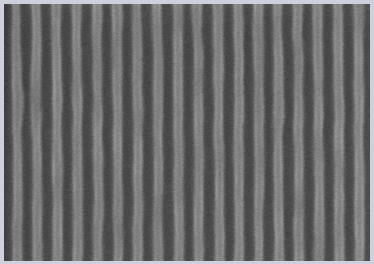




- *EUV photoabsorption is key factor for efficient secondary electrons generation.*
- *JSR developed new sensitizer using high EUV photoabsorption atom.*

Sensitivity Improvement: New Sensitizer

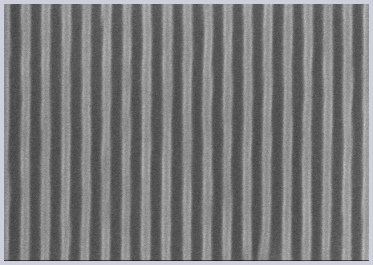
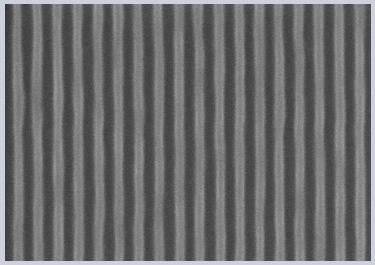
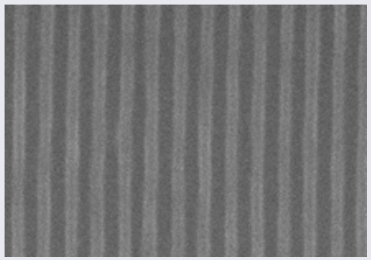
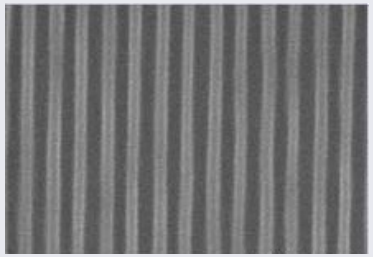
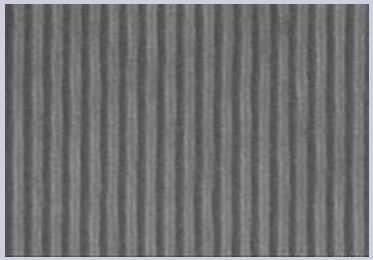
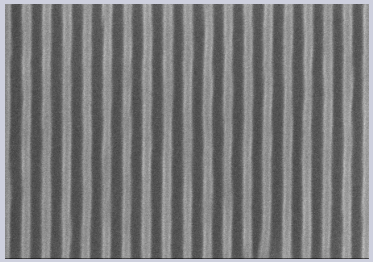
Berkeley MET, NA0.30

	Conventional CAR	CAR + New Sensitizer
SEM Image Mask: 18L36P		
Sensitivity (mJ/cm^2)	54.2	45.8
CD (nm)	17.5	18.0
LWR (nm)	2.7	2.8

16% Improvement

- *JSR new sensitizer improves EUV resist sensitivity with keeping resolution and roughness at sub-20nmhp.*
- *Outgassing of new CAR + Sensitizer system: CC=3.29nm*

Sensitivity Improvement: New Sensitizer

	Conventional CAR	CAR + New Sensitizer	Sensitivity improve
Resist A 18nmHP	 54.2mJ CD=17.5 LWR=2.7	 45.8mJ CD=18.0 LWR=2.8	16%
Resist B 22nmHP	 20.0mJ CD=23.7 LWR=8.2	 18.3mJ CD=23.7 LWR=4.1	9%
Resist C 17nmHP	 52.5mJ CD=19.1 LWR=5.3	 45.9mJ CD=19.3 LWR=6.4	13%

➢ ***New sensitizer system is applicable for various resists.***

Summary

- ✓ ***Material development for breakthrough CAR performance***
  - ***Short diffusion length PAG***
  - ***Short diffusion length and strong acidity PAG***

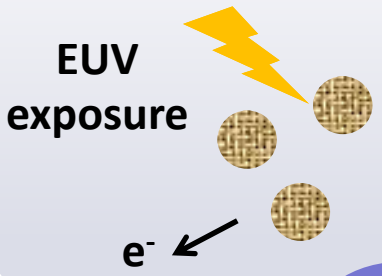
- ✓ ***JSR new high resolution CAR***
  - ***Good 16nmHP LS & 20nm IT process window on NXE3300***
  - ***13nmHP resolution on NXE 3300***
  - ***12nmHP resolution on PSI***

- ✓ ***New sensitizer development***
  - ***Sensitivity improvement with keeping resolution & roughness***
  - ***Applicable for various resist***

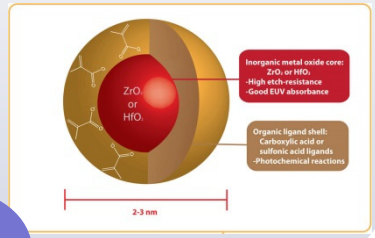
Target of 2015

Resolution:13nmhp, Sensitivity:20mJ/cm^2, LWR:2nm

❖ Sensitizer



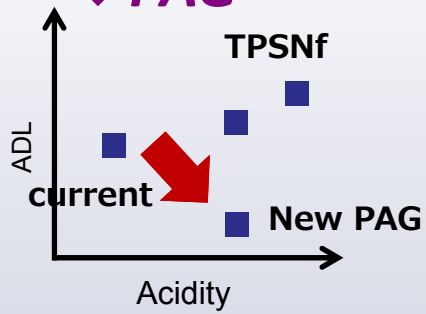
❖ Nano Particle resist*



*C. Ober & E. Giannelis, SPIE Newsroom, Sep. 15, 2014

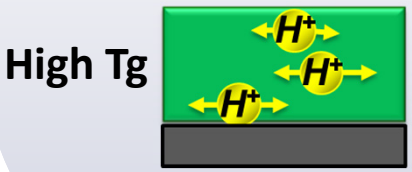
JSR target of 2015
- Sens ; 20mJ/cm2
- LER ; 2nm
- Resolution ; 13nm

❖ PAG



ADL& Acidity control

❖ Polymer



ADL control

❖ Under layer

Tri-layer for EUV

- ✓ *Investigation of various approaches to improve litho performance*
- ✓ *Collaboration with imec and partners for NXE exposure*

Acknowledgement

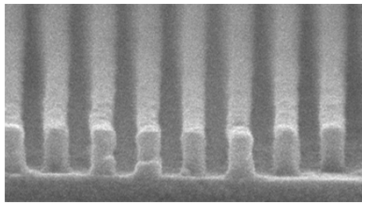
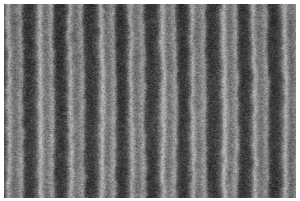
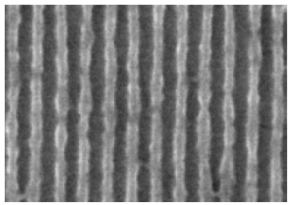
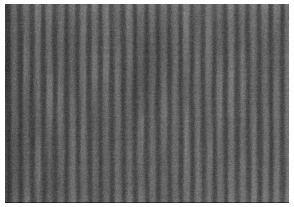
The author gratefully thanks to:

SEMATECH *for the exposure support on MET*

ASML *for the NXE3300 exposure and valuable discussion*

imec *for the close collaboration and discussion*

Thank you for your attention !!

2007	*2008*	*2010*	*2015*
40 nm LS, ArFi	*26 nm LS, ArFi DP*	*19 nm LS, EUV*	*13nm LS, EUV*
			

Materials Innovation

JSR