2012 Internal Symposium on Extreme Ultraviolet Lithography

October 1, 2012

JSR Micro

MATERIALS INNOVATION

JSR

Novel EUV Resist Materials and Process for 16 nm Half Pitch and Beyond

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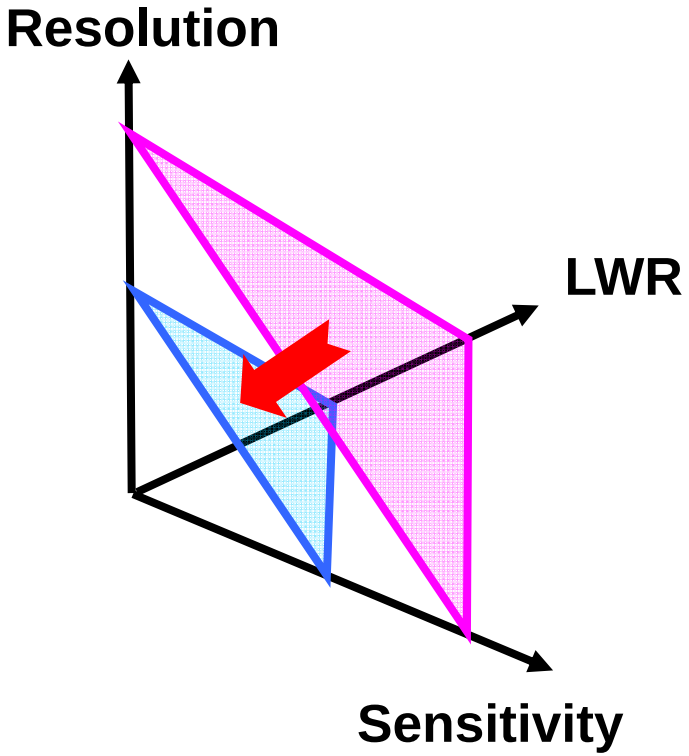
[1]JSR Micro Inc, [2]JSR Corporation

Contents

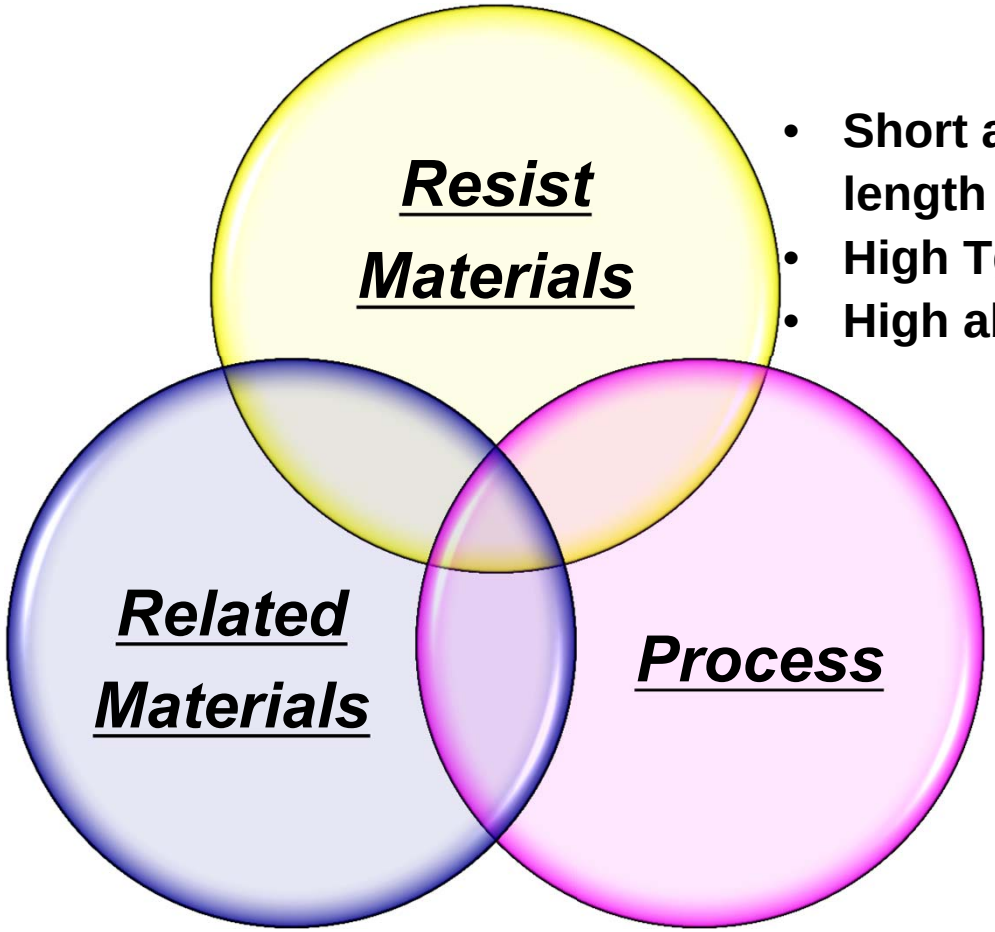
- ***Challenge for EUV Resist & JSR approaches***
- ***Development of new materials and process for Resolution, LER and Sensitivity (RLS) improvement***
- ***Combination of materials and process***
- ***Sub 22 nm CH patterning with EUV lithography and Directed Self-assembly (DSA) process***
- ***Summary***

Challenge for EUV Resist



The most difficult technical requirement is simultaneous improvement in resolution, LWR, and sensitivity (RLS).

JSR Approach for EUV Resist RLS Improvement



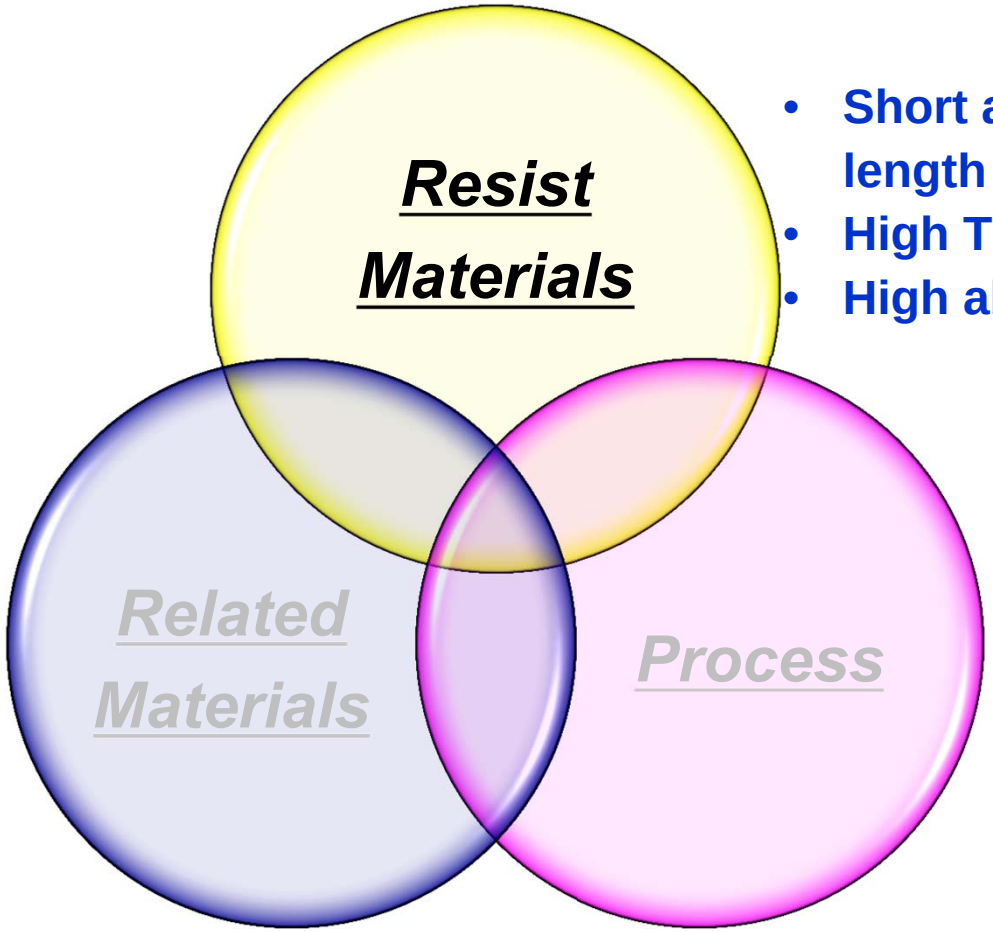
- Short acid diffusion length PAG
- High Tg resin
- High absorption resin

- Under-layer
- Top-coat

- Rinse agent
- DSA

➢ *EUV Resist RLS improvement with combination of materials and process*

EUV Resist RLS Improvement
-Resist Materials-



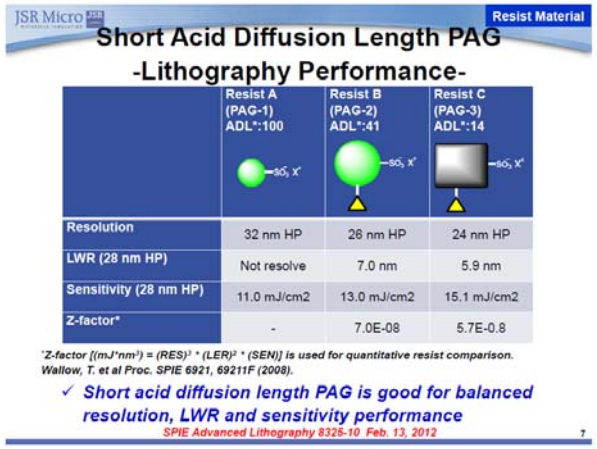
- **Short acid diffusion length PAG**
- **High Tg resin**
- **High absorption resin**

- Under-layer
- Top-coat

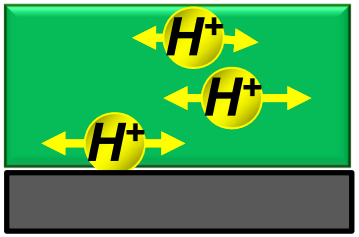
- Rinse agent
- DSA

RLS Improvement: Resist Materials

Short acid diffusion length PAG	High Tg resin	High absorption resin
Acid diffusion control	Acid diffusion control	High acid yield
LWR & Resolution	LWR & Resolution	Sensitivity



High Tg material
→Short acid diffusion length



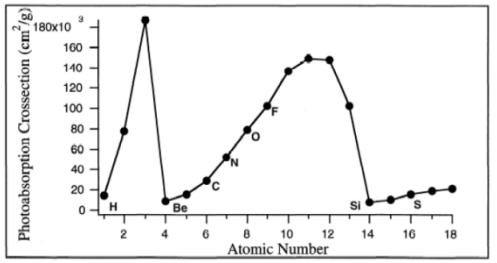


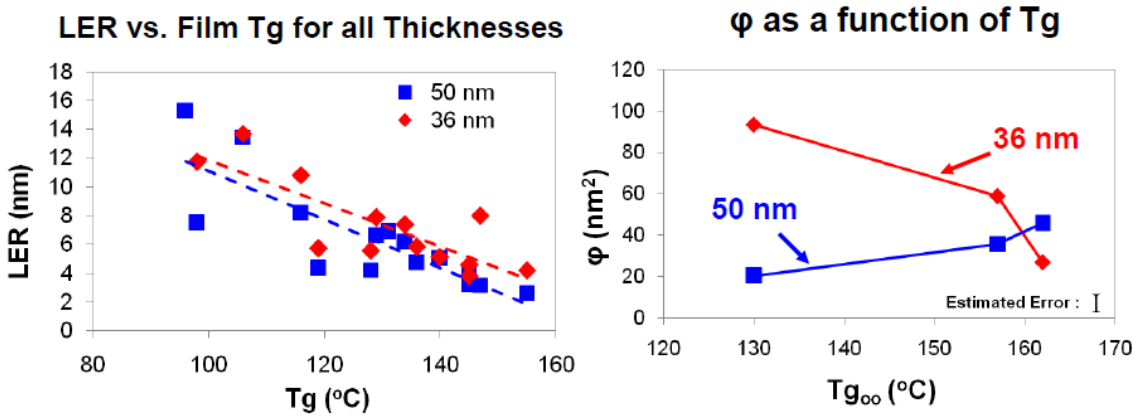
Figure 1: Elemental absorption cross-sections at 13.4 nm wavelength. Elements commonly found in photoresist materials are H, C, N, O, F, and S.

P. Dentinger et al.
SPIE 3997 (2000) 588.

- ***Improvement of RLS performance of resist with short acid diffusion length PAG was demonstrated***
- ***Effect of resin glass transition temperature (Tg) and absorption was investigated in detail***

Effect of Tg on LER

Comparison of Tg Results



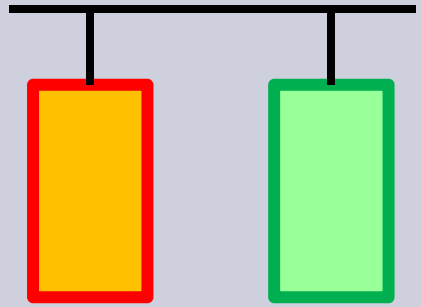
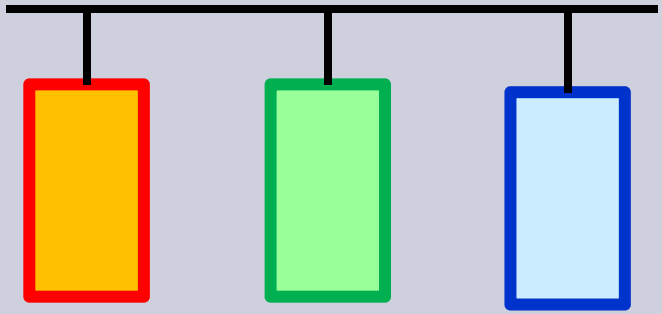
- In general, LER gets worse at higher Tg.
- Since Tg is a function of thickness, this may partially explain LER degradation.
- As Tg in increases, the φ for 36-nm lines improves while the φ for 50 nm lines gets worse.

19 10/19/11 UNIVERSITY AT ALBANY State University of New York

Brian Cardineau et al. 2011 International Symposium on EUVL

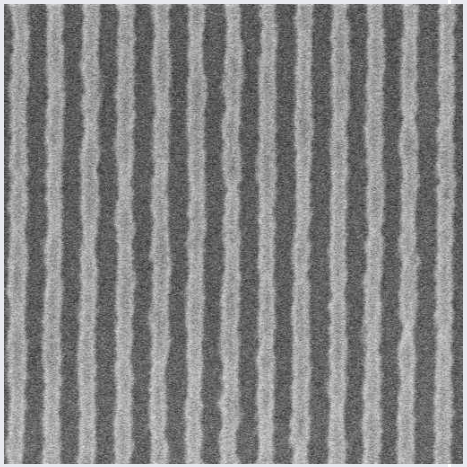
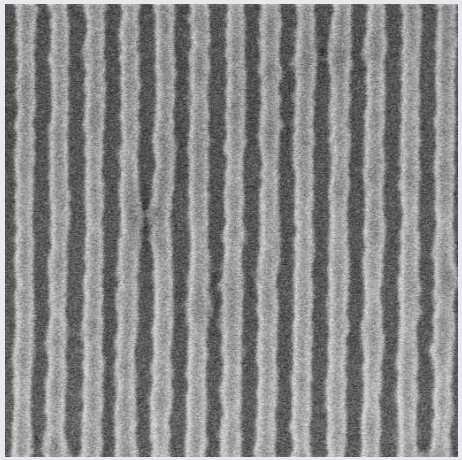
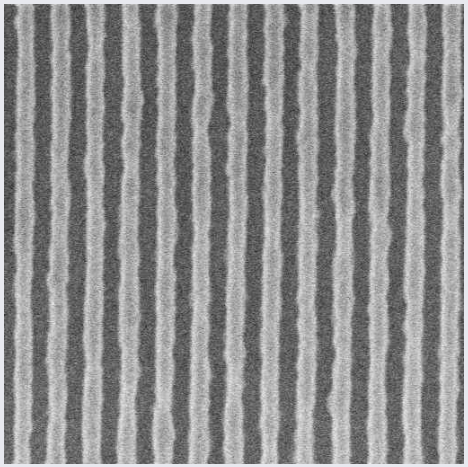
- ***JSR started to develop resin with higher Tg to understand the effect on LWR***

Development of High Tg Resin

	Std. resin	High Tg resin
Resin Composition		
Tg (°C)	Std.	Std. + 20 C
Acid diffusion length (Relative value)	100	60

- ***High Tg EUV resin was prepared by incorporating high Tg monomer unit into standard resin***
  - ***Tg increased by 20 C by adding high Tg monomer to std. resin***
  - ***Acid diffusion length become short by 40% by applying high Tg resin.***

Resin Tg Impact on RLS Performance

Resist	Resist A	Resist B	Resist B
Resin Tg (°C)	Std	Std + 20	Std + 20
PEB	Std	Std	High
Sensitivity	16.7 mJ/cm^2	18.6 mJ/cm^2	15.4 mJ/cm^2
LWR	6.2 nm	4.6 nm	5.0 nm
Z-factor	5.68E-08	3.56E-08	3.32E-08
26 nm hp			

- ***Resist with high Tg resin shows good LWR than std resist***
- ***Combination of high Tg resin and high PEB improved RLS performance***

Development of High Absorption Resin

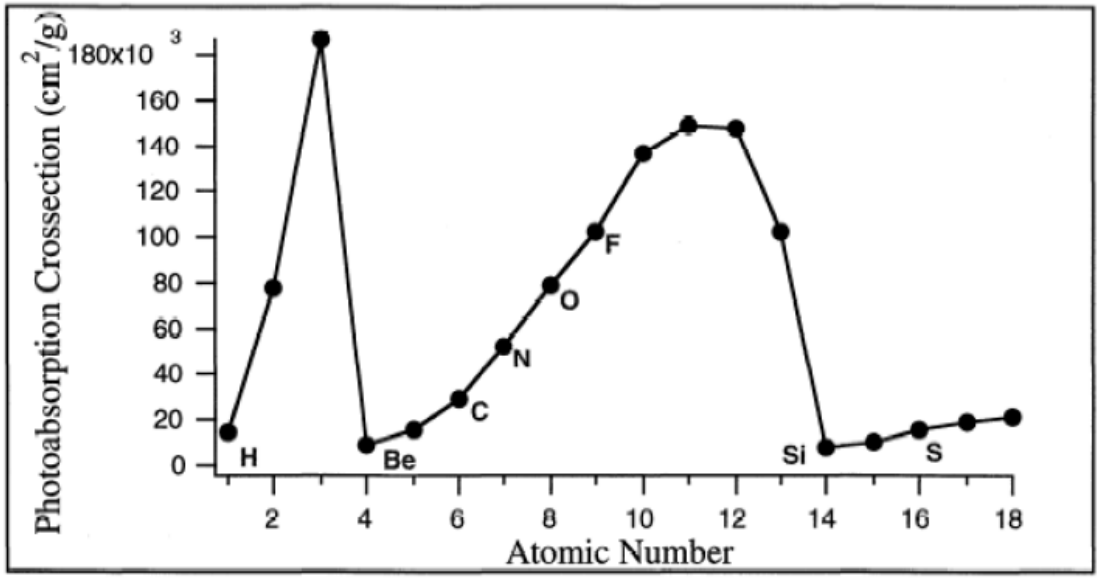
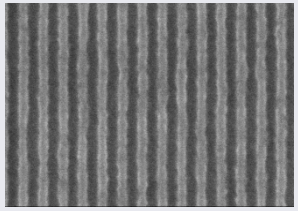
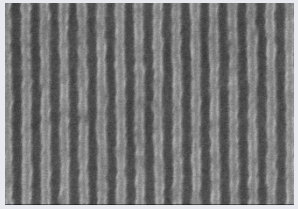
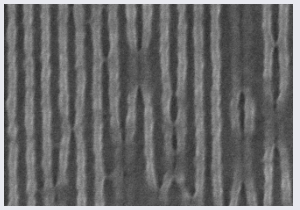
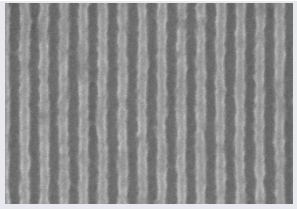
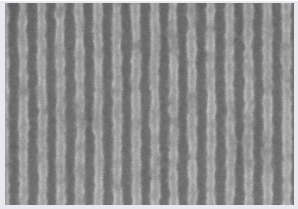
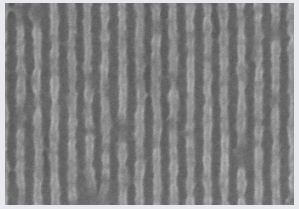


Figure 1: Elemental absorption cross-sections at 13.4 nm wavelength. Elements commonly found in photoresist materials are H, C, N, O, F, and S.

P. Dentinger et al. SPIE 3997, 588 (2000).

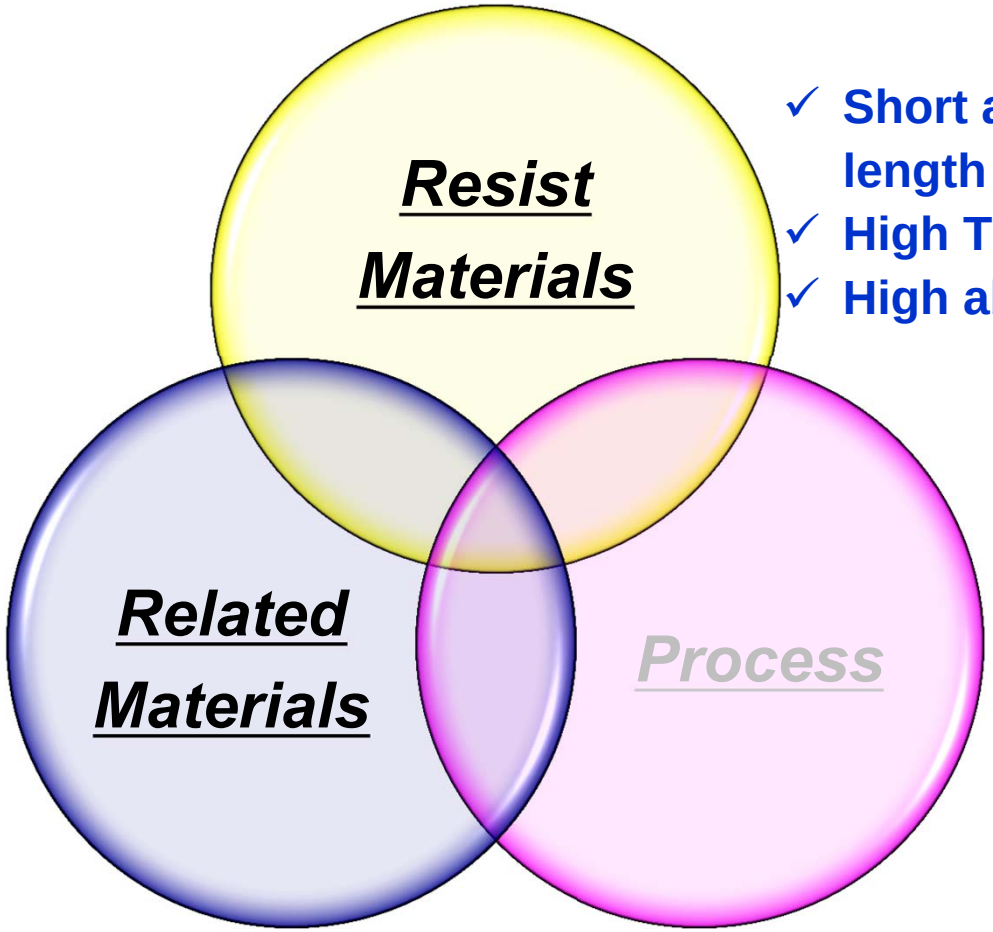
- ***Resin including high absorption atom was developed to improve sensitivity***

Development of High Absorption Resin

EUV Resist with Std Resin	HP	22 nm HP	20 nm HP	19 nm HP
	Sensitivity	17.2mJ/cm2	17.2mJ/cm2	17.2mJ/cm2
	LWR	5.8nm	5.5nm	-
	Image			
EUV Resist with High absorption resin	HP	22 nm HP	20 nm HP	19 nm HP
	Sensitivity	15.0mJ/cm2	15.0mJ/cm2	15.0mJ/cm2
	LWR	5.5nm	5.8nm	-
	Image			

- ***Sensitivity improved by 15 % with high absorption resin***

EUV Resist RLS Improvement
-EUV lithography related materials-

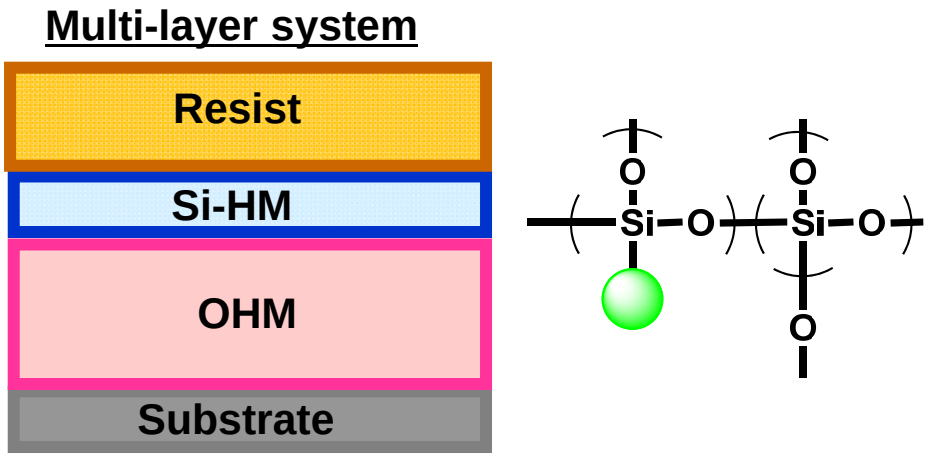


- ✓ Short acid diffusion length PAG
- ✓ High Tg resin
- ✓ High absorption resin

- Under-layer
- Top-coat

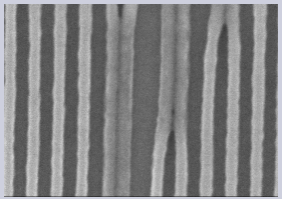
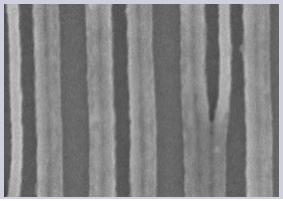
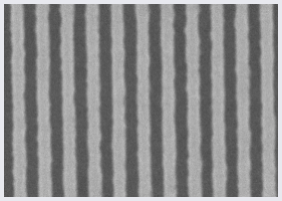
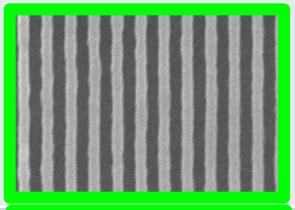
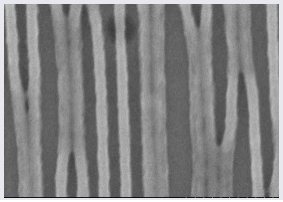
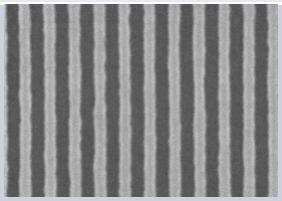
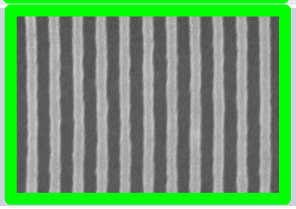
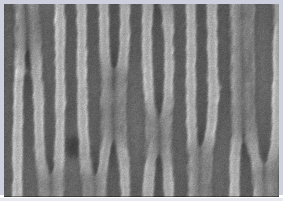
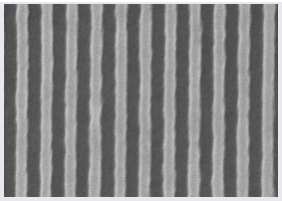
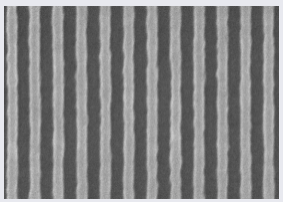
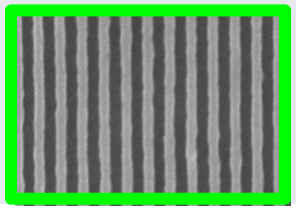
- Rinse agent
- DSA

Development of Under Layer (UL) – Si-HM



- ✓ ***Si-HMs in different contact angle were evaluated to understand the effect of Si-HM composition on resist pattern line collapse***

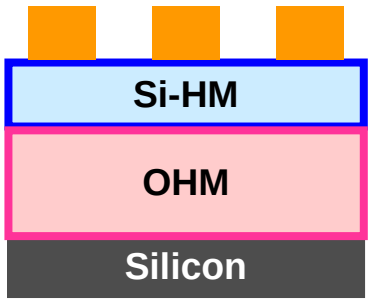
Si-HM Impact on Resolution

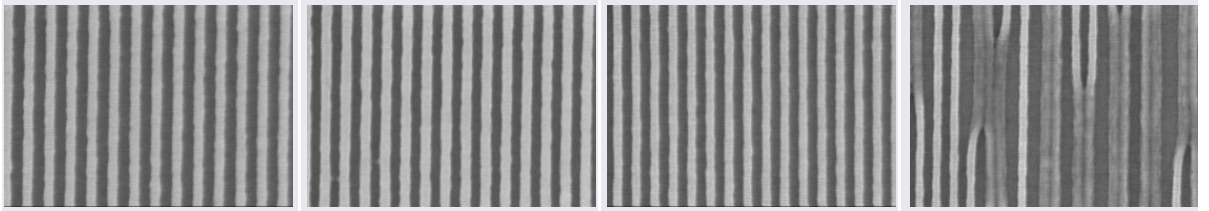
Si-HM	30 nm HP	28 nm HP	26 nm HP
Si-HM-A Contact angle :100 (relative value)			
Si-HM-B Contact angle :104 (relative value)			
Si-HM-C Contact angle :106 (relative value)			
Si-HM-D Contact angle :109 (relative value)			

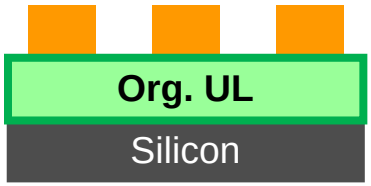
Exp. NA 0.30, Dipole

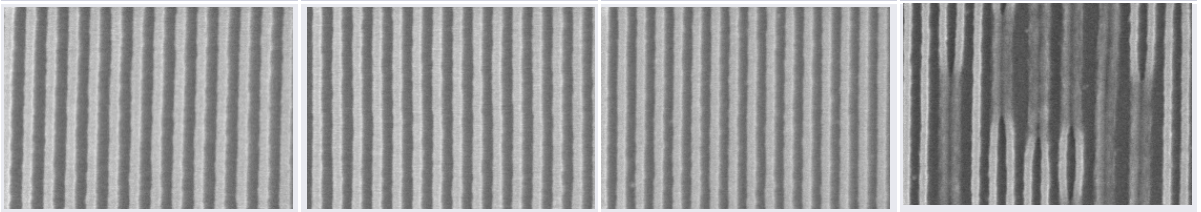
- ✓ *Higher contact angle of Si-HM improves resist pattern collapse*
- ✓ *Surface property is the key factor for improvement of pattern collapse*

Si-HM impact on Sensitivity



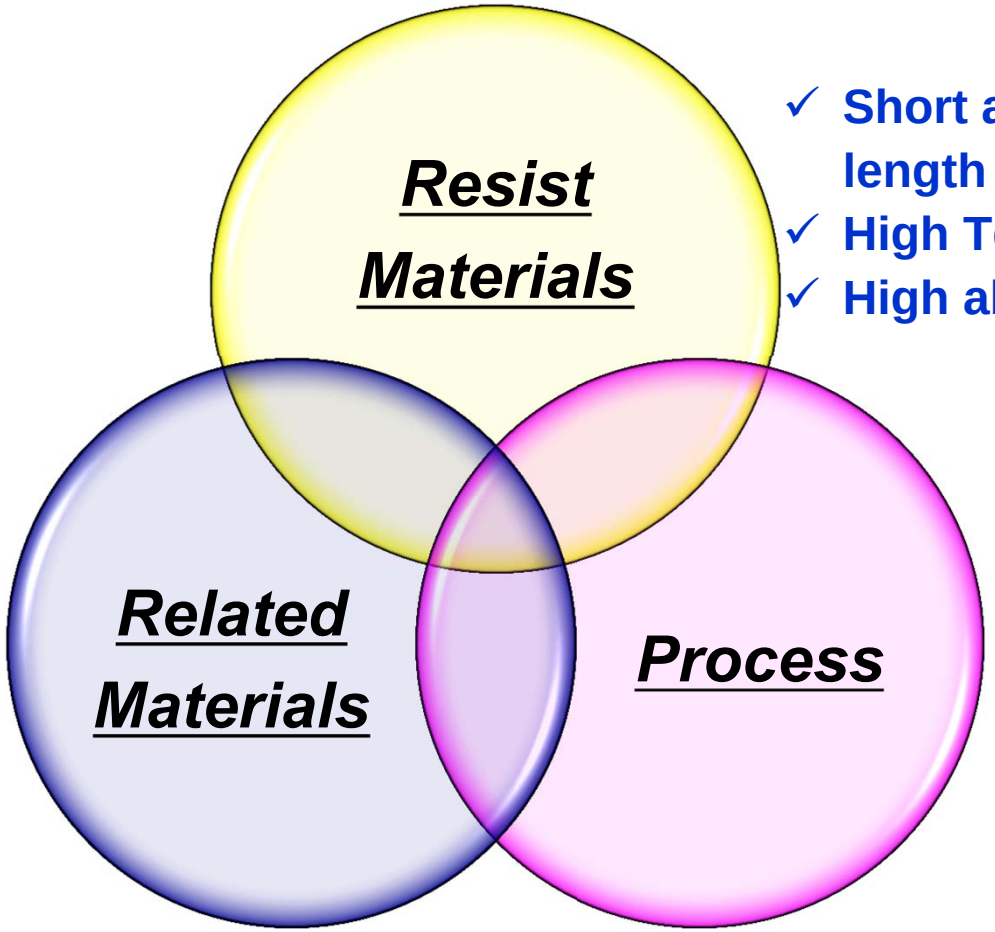
HP	32 nm HP	30 nm HP	28 nm HP	26 nm HP
Sensitivity	16.0mJ/cm^2	16.0mJ/cm^2	16.0mJ/cm^2	16.0mJ/cm^2
LWR	4.1nm	3.7nm	4.3nm	-
Image				



HP	32 nm HP	30 nm HP	28 nm HP	26 nm HP
Sensitivity	18.4mJ/cm^2	18.4mJ/cm^2	18.4mJ/cm^2	18.4mJ/cm^2
LWR	4.0nm	4.0nm	3.6nm	-
Image				

➢ ***Sensitivity improved by 15 % with Si-HM.***

EUV Resist RLS Improvement
-Process-



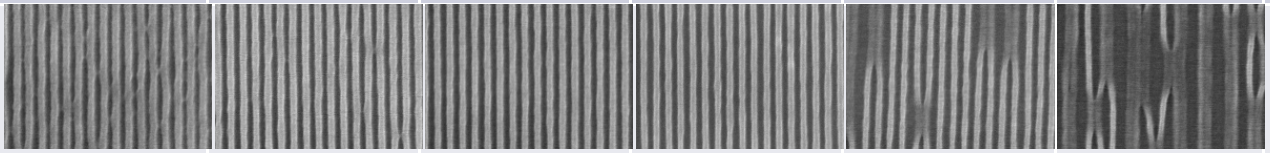
- ✓ Short acid diffusion length PAG
- ✓ High Tg resin
- ✓ High absorption resin

- ✓ Under-layer
- • Top-coat

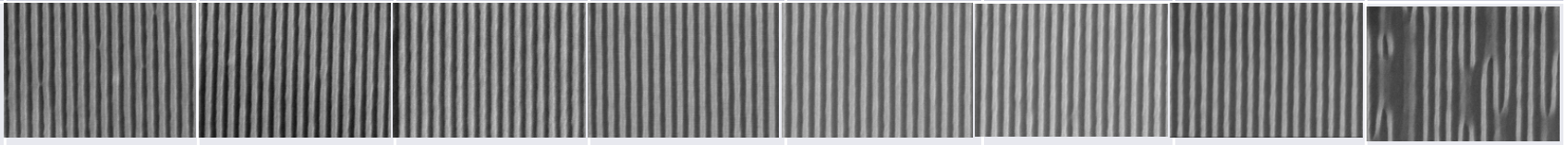
- • Rinse agent
- • DSA

FIRM™ Rinse* Process Impact for Pattern Collapse

Without FIRM™ rinse

Dose (mJ/cm²)	28.9	30.7	34.2	36.0	37.8	39.5		
CD(nm)		22.2	20.9	19.8	-	-	-	-
20 nm HP								

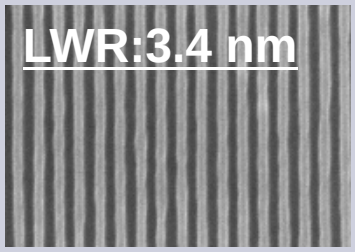
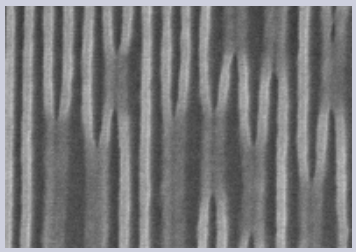
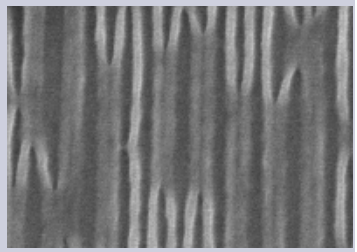
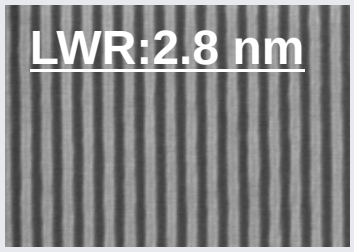
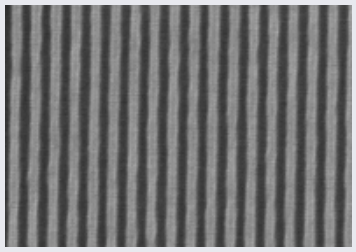
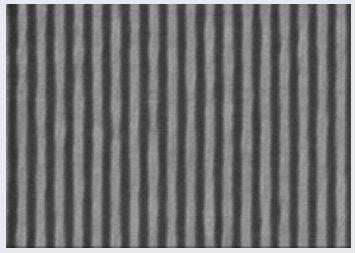
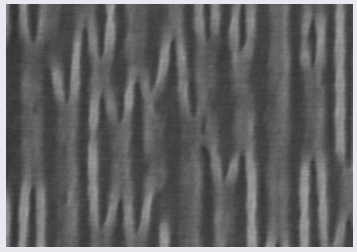
With FIRM™ rinse

Dose (mJ/cm²)	28.9	30.7	34.2	36.0	37.8	39.5	41.3	43.1
CD(nm)	21.5	20.9	20.1	20.0	19.0	18.3	16.8	-
20 nm HP								

*FIRM™ Extreme™ 12

- ***FIRM™ rinse process improves pattern collapse margin***

FIRM™ Rinse*Process Impact for Resolution and LWR

HP	20 nm HP	19 nm HP	18 nm HP	17 nm HP
Without FIRM™ Rinse	 LWR:3.4 nm			
With FIRM™ Rinse	 LWR:2.8 nm			

*FIRM™ Extreme™ 12

- ***Higher resolution observed with rinse process***
- ***LWR improved by 15 % with rinse process***

Contents

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- *Development of new materials and process for Resolution, LER and Sensitivity (RLS) improvement*
- ***Combination of materials and process***
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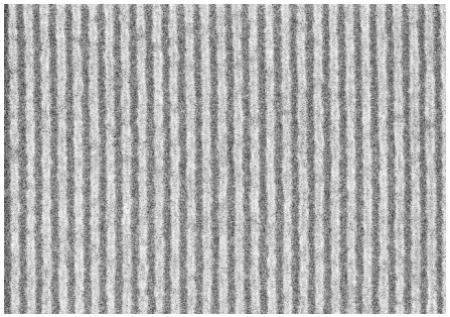
- *Summary*

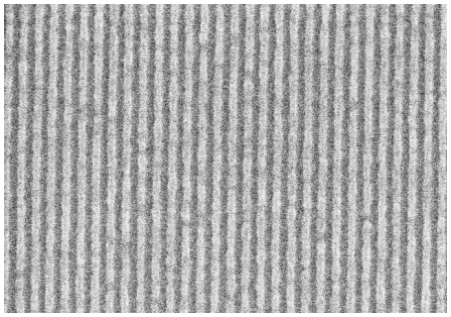
Exposure result on SEMATECH Berkeley MET

LS Ultimate resolution

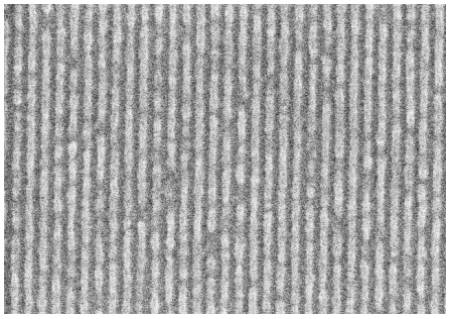
16nm LS



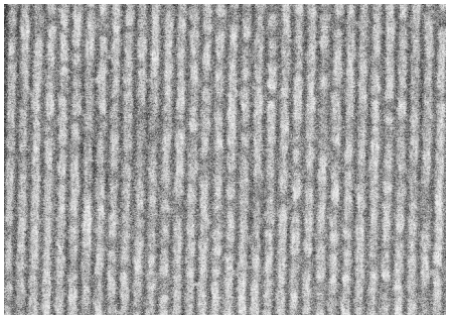
15nm LS



14nm LS



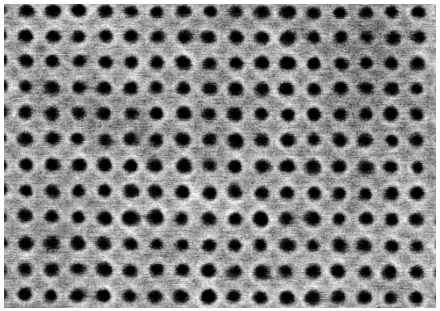
13nm LS



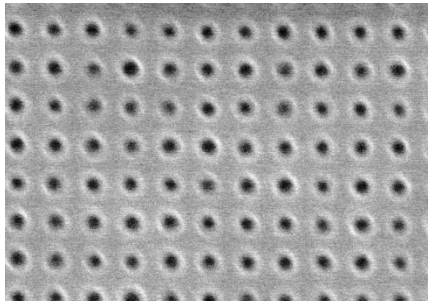
Berkeley MET, NA0.3, Pseudo PSM
Sensitivity: 44mJ/cm^2

CH Ultimate resolution

20nmC40nmP



20nmC60nmP



Sen. 63mJ/cm^2

Sen.105mJ/cm^2

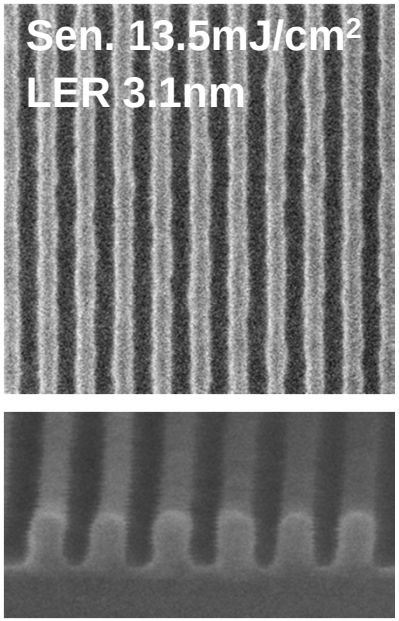
Berkeley MET, NA0.3, Quadrupole

- ***JSR EUV resist has the potential to achieve of 14 nm LS and 20 nm CH patterns***

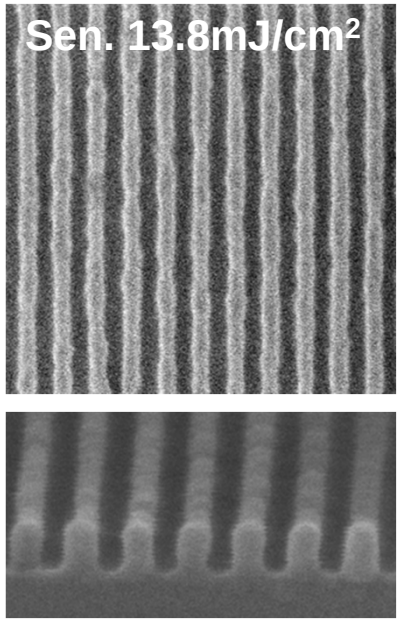
Exposure result on imec NXE:3100

LS Performance

22nm LS



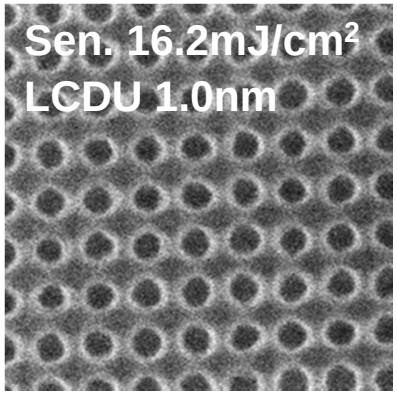
20nm LS



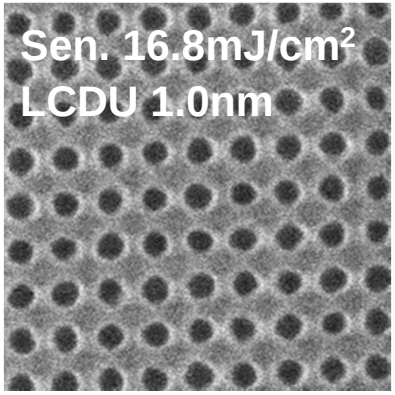
Imec's NXE3100, NA0.25, Dipole60X
With FIRM™ rinse.
LER: 3σ

CH Performance

28nm CH



26nm CH



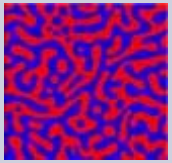
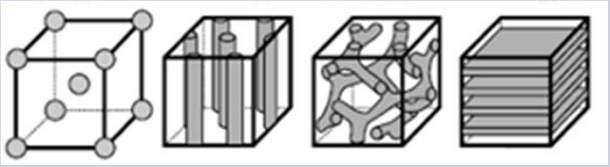
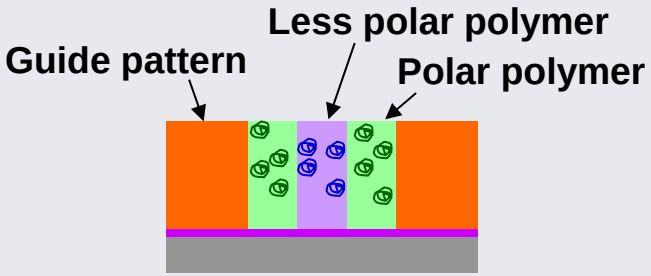
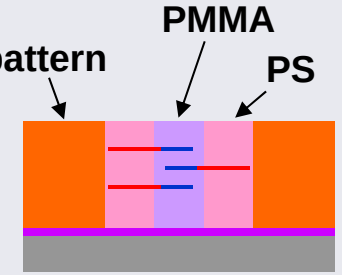
Imec's NXE3100, NA0.25, Quasar45
LCDU: 1σ

- ***JSR EUV resist shows good RLS and LCDU performance for 2x nm generation***

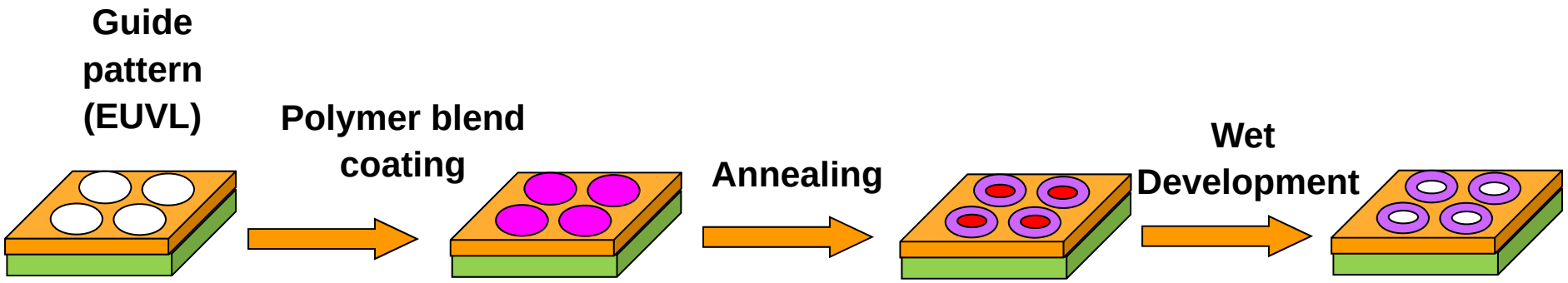
Contents

- *Challenge for EUV Resist & JSR approaches*
- *Development of new materials and process for Resolution, LER and Sensitivity (RLS) improvement*
- *Combination of materials and process*
- ***Sub 22 nm CH patterning with EUV lithography and Directed Self-assembly (DSA) process***
- *Summary*

EUV Lithography with DSA

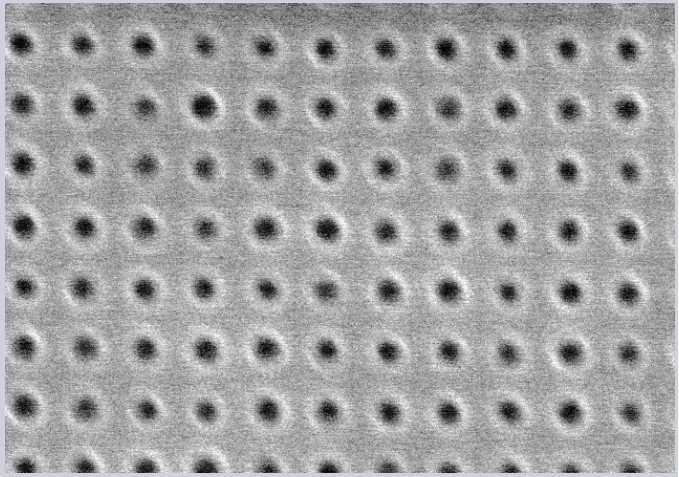
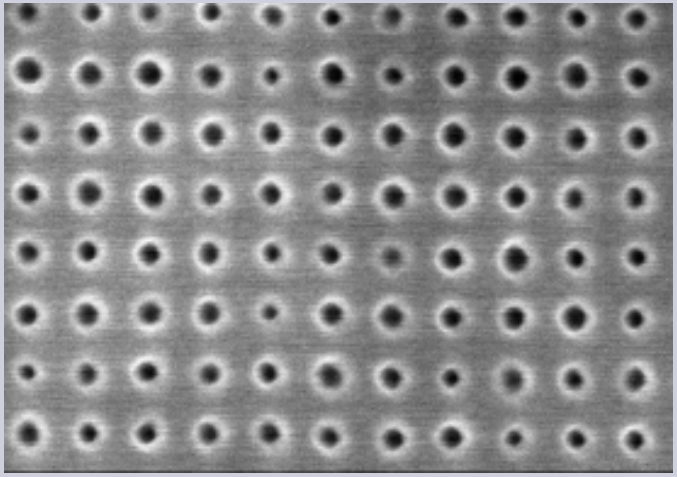
	Blend type (PolymerA/PolymerB)	BCP type (PS-*b*-PMMA)
Polymer phase separation	 • No specific dimension, morphology, or periodicity	 • Intrinsic dimension and pre-determined morphology
CH Shrink	 • Polar polymer remains for pattern shrink and less polar polymer is removed	 • PS remains for pattern shrink and PMMA is removed
Development	• Organic solvent	• Dry development • UV irradiation with polar solvent
Anneal condition	• 120 -150 °C	• 200 -250 °C

EUV Lithography with DSA



- ✓ ***Polymer blend DSA material was investigated for CH shrink process***

EUV Lithography with DSA

	EUV lithography	EUV + DSA
Sensitivity	105 mJ/cm^2	32.1 mJ/cm^2
LCDU	4.6 nm	4.9 nm
20 nm H 60 nm P		

- ✓ *EUV lithography followed by polymer blend DSA process achieved 20 nm contact hole patterns*
- ✓ *EUV+DSA process improves resist sensitivity*

Summary

- ✓ ***Material & process development for RLS improvement***
  - ***New high Tg or high absorption resin shows good balance between LWR and sensitivity***
  - ***Si-HM UL improves resolution and sensitivity***
  - ***Rinse agent improves resolution and LWR***
  - ***EUVL with polymer blend DSA process improves sensitivity for CH process***
- ✓ ***Combination of material and process for ≤ 22 nm hp patterning***
  - ***JSR EUV resist achieved 14 nm LS and 20 nm CH resolution on SEMATECH Berkeley MET***
  - ***JSR EUV resist shows good RLS and LDCU performance for 2x nm hp generation on imec NXE:3100.***

Acknowledgment

The authors gratefully thank imec, SEMATECH, and CXRO for the close collaboration

Thank you for your attention !!

Materials Innovation

JSR

With chemistry, we can.