JSR SEMICONDUCTOR MATERIALS LABORATORY

Progress in EUV resist development

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2007 EUVL Symposium

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- Critical issues of EUV lithography
- Current status and issues of EUV resist
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Critical issues of EUV lithography

1. Reliable power source & collector module
2. Resist resolution, sensitivity and LER met simultaneously
3. Availability of defect free mask
4. Reticle protection during storage and use
5. Projection and illuminator optics quality & life time

2006 EUVL symposium（Barcelona)

Resist performance is one of the critical issues.

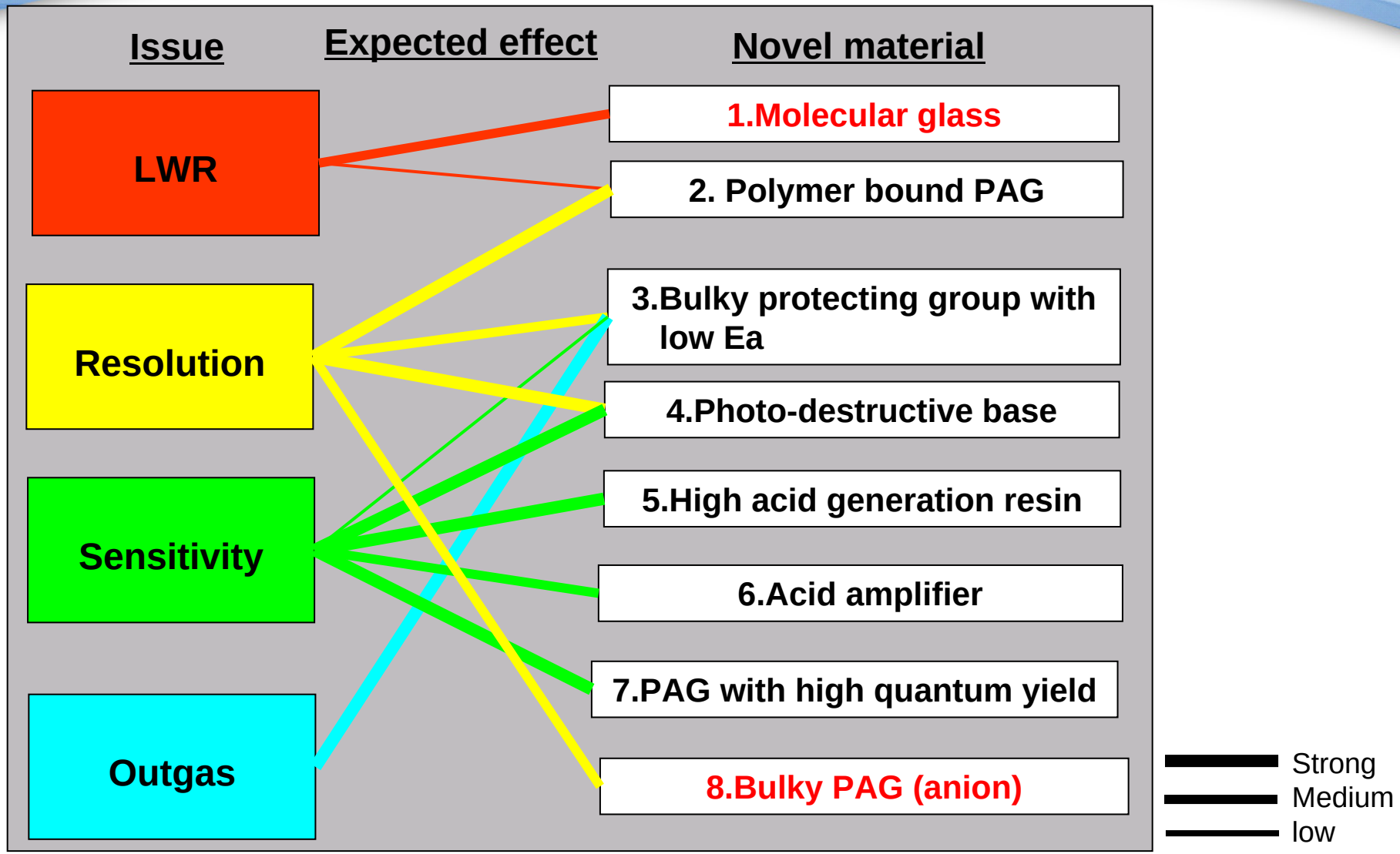
Current status and issues of EUV resist

Performance	JSR CAR (Polymer type)	Specification (ITRS2006)
Sensitivity	20-30 mJ/cm^2	5-15 mJ/cm^2
LWR-3σ (Low frequency)	5-7 nm (45nmL/S)	1.7 nm
Resolution (1:1 L/S)	30 nm (resolution limit)	32 nm (with process margin)
Resolution (Iso line)	?	21 nm (with process margin)
Outgas	1.0×10^{14}-10^{15} molecules/cm^2	6.5×10^{14} molecules/cm^2*

*:SEMATECH's spec for microexposure tool

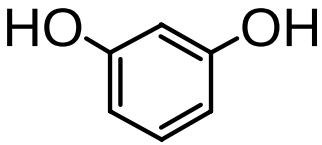
For 32nm L/S and beyond, sensitivity, LWR and resolution are critical issues.

Counter action for issues



Status of 1.Molecular glass and 8. Bulky PAG are reported.

New molecular glass, Noria [1)]



Resorcinol

+

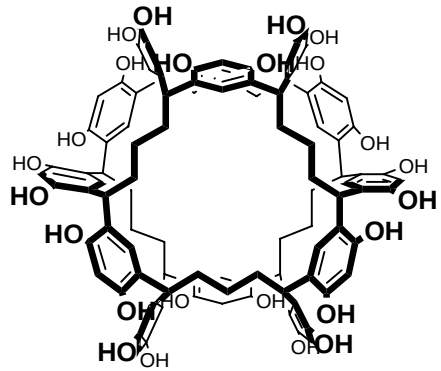
$OHC\text{-}(CH_2)_3\text{-}CHO$

Glutaraldehyde (1,5-Pentanedial)

HCl

80 ^{o}C, 48 h

in Ethanol



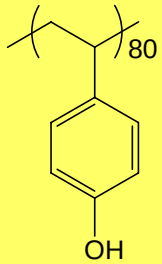
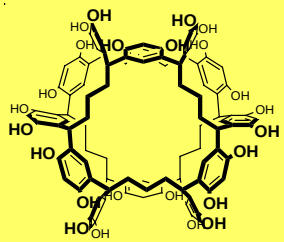
Noria

79% Yield

- **Prof. Nishikubo in Kanagawa Univ. developed new molecular glass, Noria.**
- **Noria has rigid structure and is expected to show high thermal stability.**

1) Nishikubo *et al*., *Angew. Chem. Int. Ed*. 2006, *45*, 7948-7952

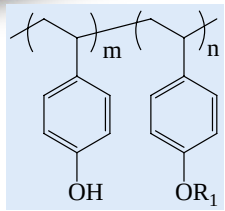
Physical property comparison between PHS resin and Noria

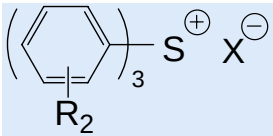
Physical property	PHS resin	Noria
		
Molecular weight (Mw)	Approx.10000	Approx.2000
Polydispersity	>1.1	1.0
Molecular size* (calculation)	Approx.7 nm	Approx.2nm

*Calculation method: MD

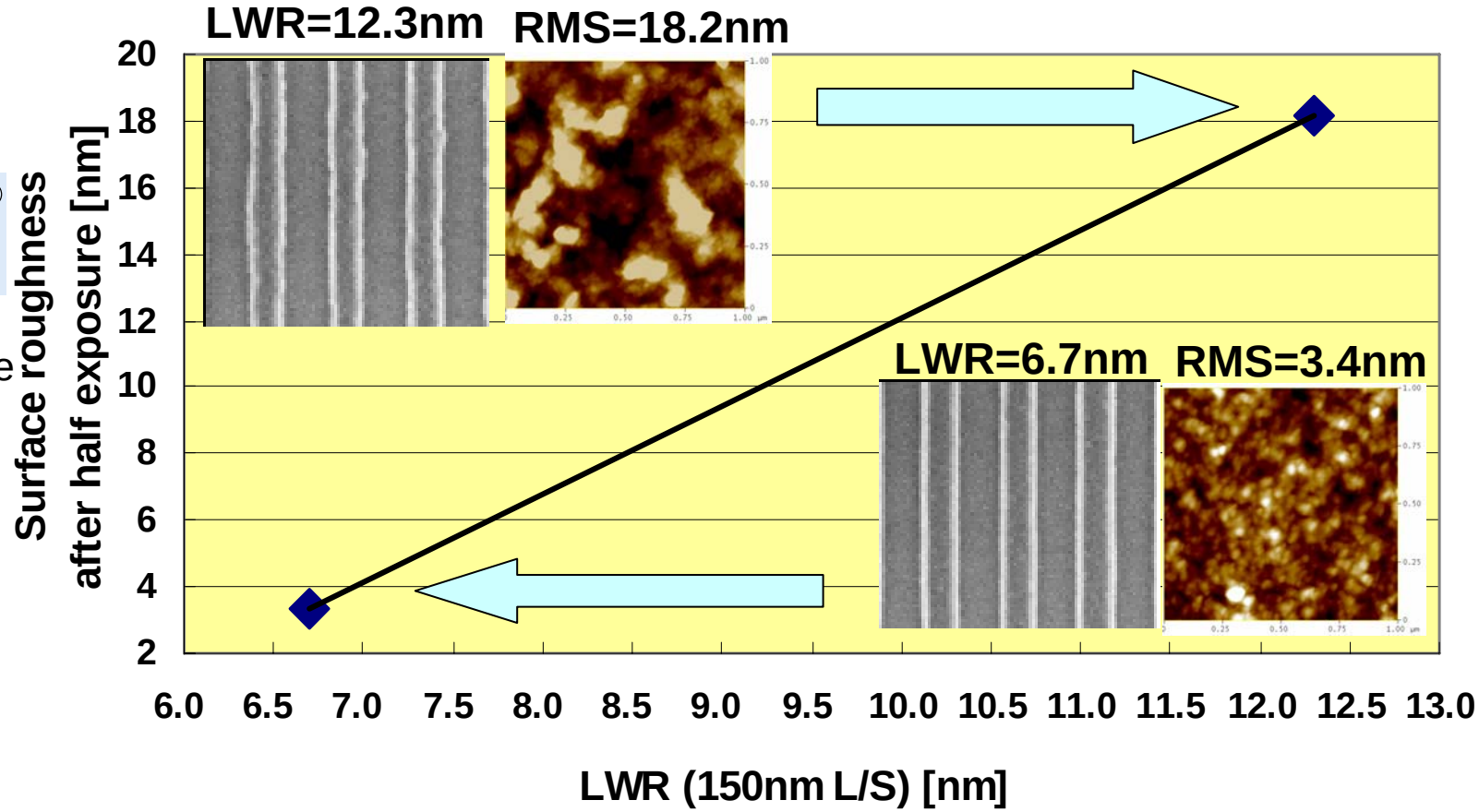
Noria gives smaller molecular size than PHS resin in calculation.

LWR vs. surface roughness (RMS)





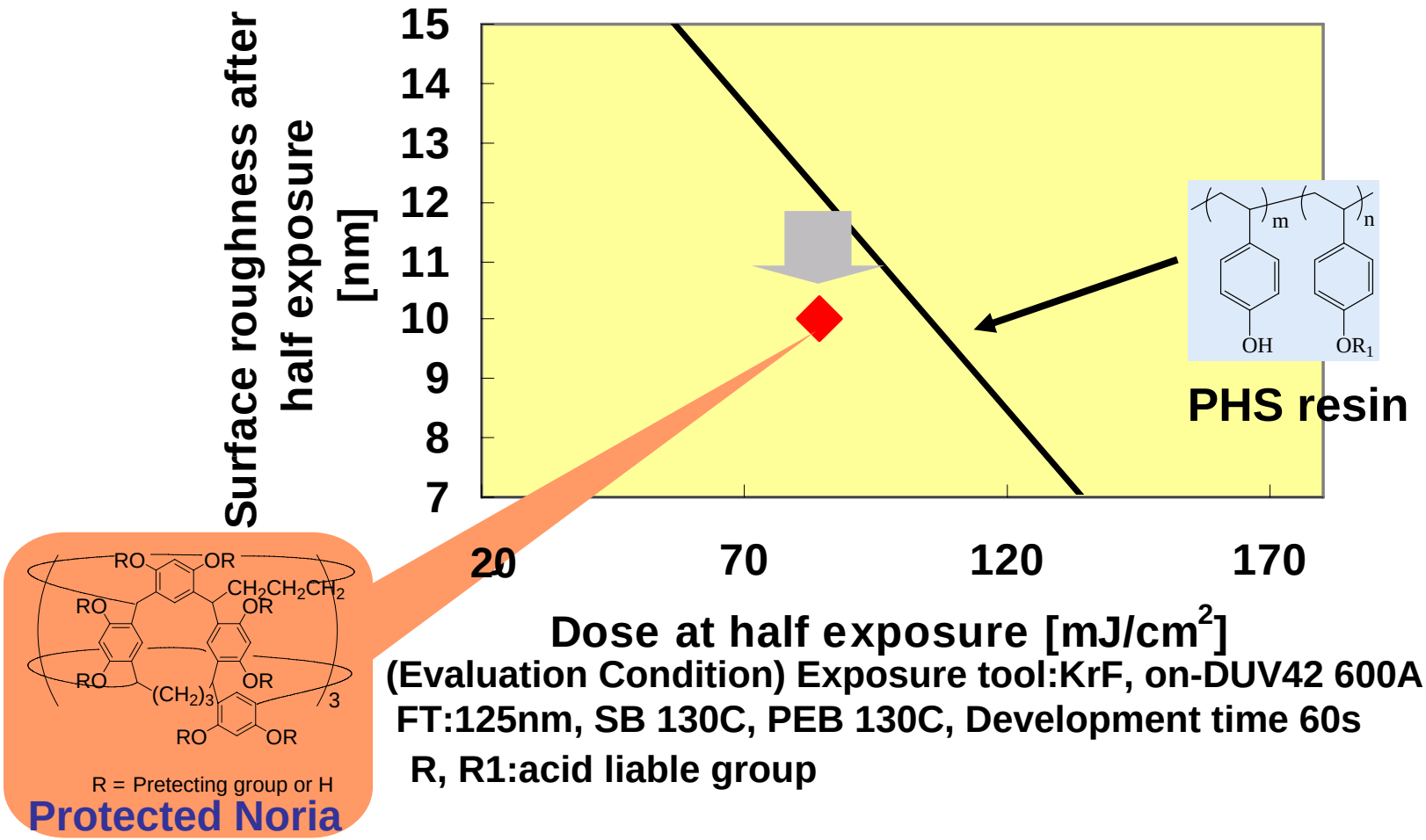
R_1: acid labile group



(Evaluation Condition) Exposure tool:KrF, on-DUV42 600A, FT:125nm, SB 130C, PEB 130C, Development time 60s

Correlation between LWR and surface roughness was observed.

Surface roughness measurement

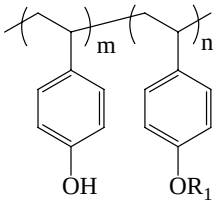
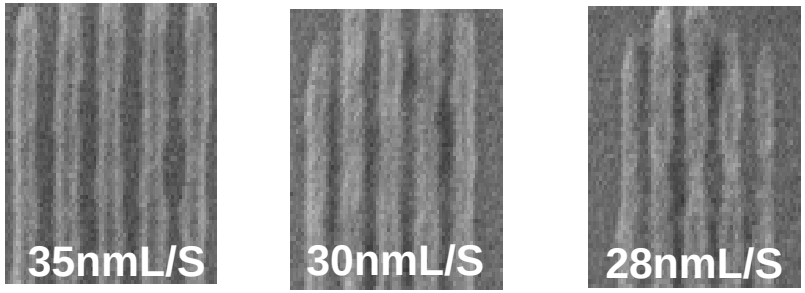
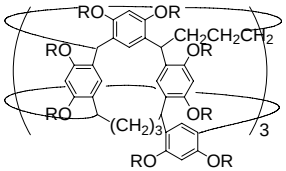
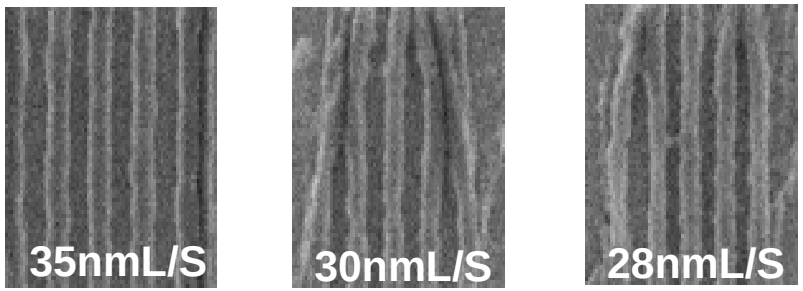


(Evaluation Condition) Exposure tool:KrF, on-DUV42 600A, FT:125nm, SB 130C, PEB 130C, Development time 60s

R, R1:acid liable group

- **Protected Noria gave smaller surface roughness than PHS resin.**
- **Noria is expected to give better LWR than resin.**

EUV exposure result (resolution, SFET)

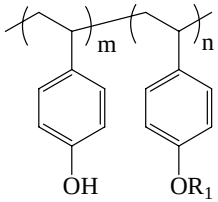
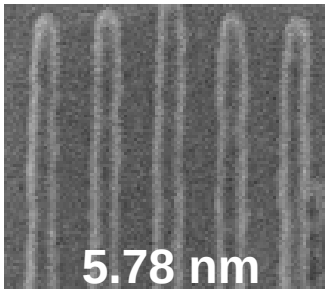
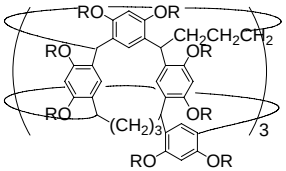
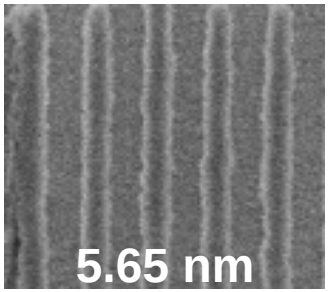
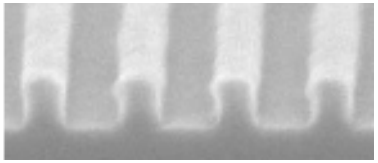
Resist	Character	Sensitivity at 45 nm L/S	Resolution
A	PHS resin 	20.36 mJ/cm²	
B	Noria  R = Pretecting group or H	25.80 mJ/cm²	

(Evaluation Condition) Exposure tool:SFET, on-Bare-Si, FT:90 nm (A), 60 nm (B)

Courtesy of Selete

Resist B (Noria) showed similar resolution to resist A(PHS resin).

EUV exposure result (LWR, SFET)

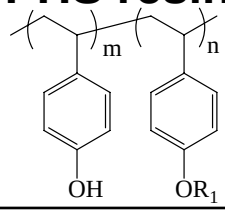
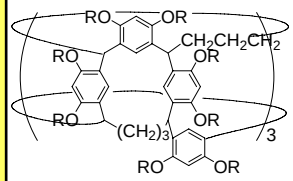
Resist	Character	LWR at 45nm L/S	Cross-section at 45nm L/S
A	PHS resin 		Under evaluation
B	Noria  R = Pretecting group or H		

(Evaluation Condition) Exposure tool:SFET, on-Bare-Si, FT:90 nm (A), 60 nm (B)

Courtesy of Selete

Resist B (Noria) showed similar LWR to resist A (PHS resin).

Performance comparison between PHS resin and Noria (SFET)

Resist	Character	Sensitivity at 45 nm L/S	Resolution	LWR at 45nm L/S
A	PHS resin 	20.36 mJ/cm^2	30 nm L/S	5.78 nm
B	Noria  R = Pretecting group or H	25.80 mJ/cm^2	30-35 nm L/S	5.65 nm

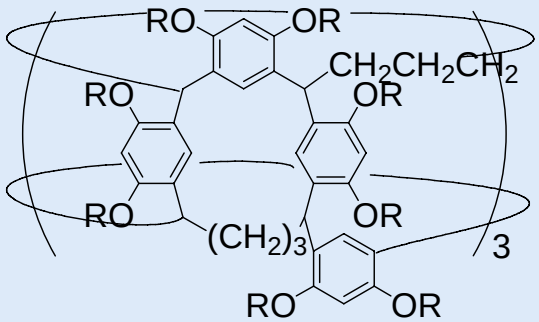
(Evaluation Condition) Exposure tool:SFET, on-Bare-Si, FT:90 nm (A), 60 nm (B)

Courtesy of Selete

Similar performance was observed.

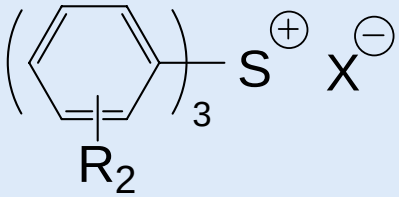
Improvement of resolution -bulky PAG-

Design of resist B



R = Pretecting group or H

Noria



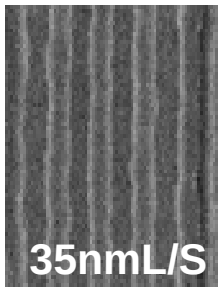
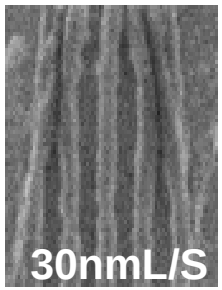
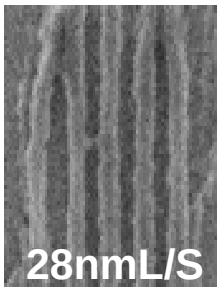
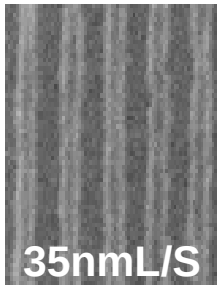
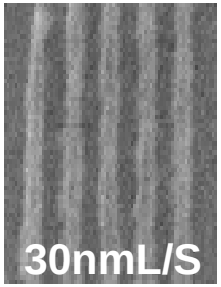
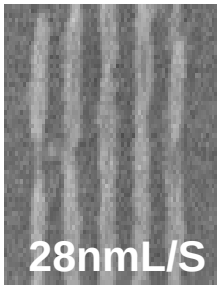
TPS salt (Small anion)

Resist	PAG	Van der Waals volume of anion [Å^3]*	Acid diffusion coefficient
B	TPS salt (Small anion)	Approx.100	Under measurement
C	TPS salt (Bulky anion)	Approx.200	

*Van der waals volume was calculated by Winmoster.

To improve resolution, TPS salt with bulky anion was applied to Noria.

EUV exposure result (resolution, SFET)

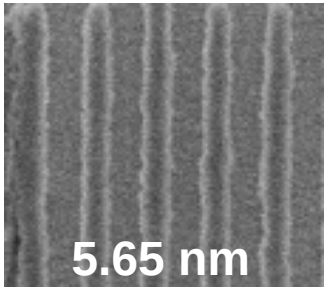
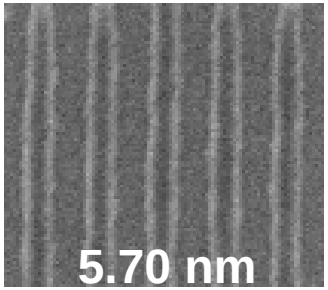
Resist	Character	Sensitivity at 45 nm L/S	Resolution		
B	Noria TPS salt (Small anion)	25.80 mJ/cm^2	 35nmL/S	 30nmL/S	 28nmL/S
C	Noria TPS salt (Bulky anion)	26.33 mJ/cm^2	 35nmL/S	 30nmL/S	 28nmL/S

(Evaluation Condition) Exposure tool:SFET, on-Bare-Si, FT:60 nm,

Courtesy of Selete

Resist C containing bulky PAG resolved 28 nm L/S patterns.

EUV exposure result (LWR, SFET)

Resist	Character	LWR at 45nm L/S
B	Noria TPS salt (Small anion)	
C	Noria TPS salt (Bulky anion)	

(Evaluation Condition) Exposure tool:SFET, on-Bare-Si, FT:60 nm,

Courtesy of Selete

Resist C containing bulky PAG did not increase LWR.

Summary of exposure result (SFET)

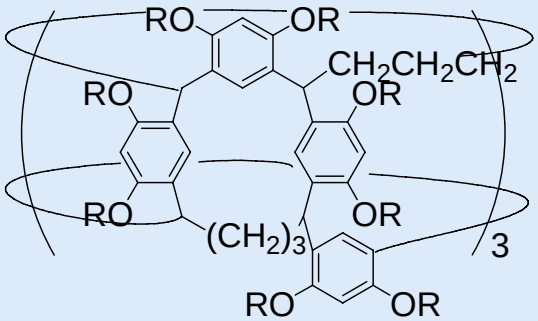
Resist	Character	Sensitivity at 45 nm L/S	Resolution	LWR at 45nm L/S
A	PHS resin	20.36 mJ/cm^2	30 nm L/S	5.78 nm
B	Noria TPS salt (Small anion)	25.80 mJ/cm^2	30-35 nm L/S	5.65 nm
C	Noria TPS salt (Bulky anion)	26.33 mJ/cm^2	28 nm L/S	5.70 nm

Courtesy of Selete

Resist C (Noria and bulky PAG) showed the best performance in this experiment.

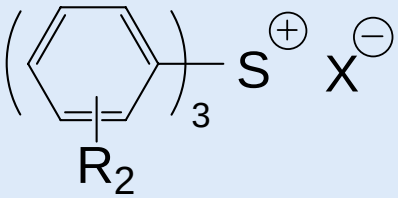
Future action of Noria

Current design



R = Pretecting group or H

Protected Noria



TPS salt (Bulky anion)

<u>To improve performance, following items will be executed.</u>

1. New protecting group (low Ea type etc.)

2. Optimization of PAG and quencher

Summary

- In this study, the performance of new molecular glass, Noria was investigated.
- From surface roughness measurement, Noria is expected to give better LWR than resin.
- Noria based resist containing bulky PAG showed best performance in our experiment.
- To improve performance of Noria, new protecting group and optimization of resist formulation will be executed.

Acknowledgement

The authors would like to thank

Selete for EUV exposure

(“SFET” is supported by NEDO).