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JSR SEMICONDUCTOR MATERIALS LABORATORY

Development of Chemically Amplified EUV resist for 22 nm half pich and beyond

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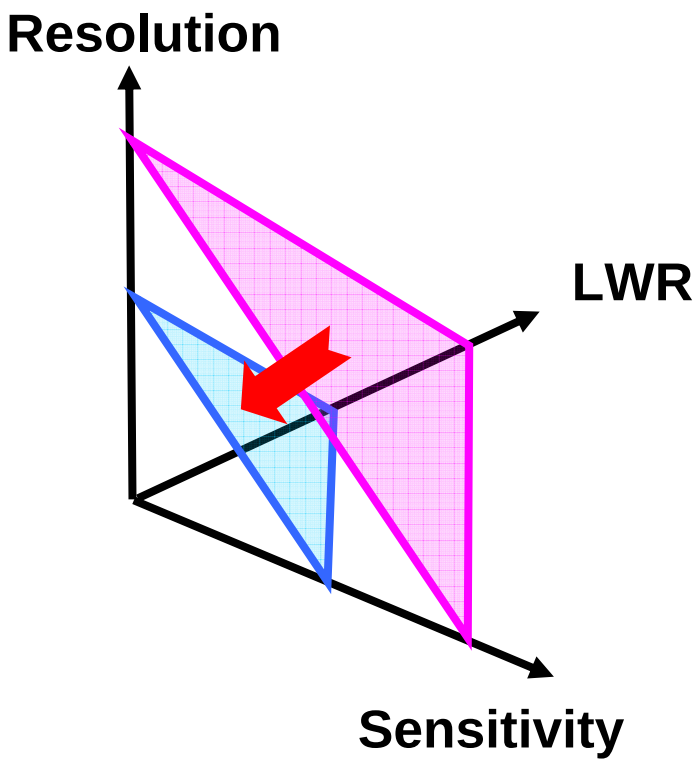
Outline

- ***Critical Requirements of EUV resist***
- ***Materials to improve RLS***
  - ***Materials to improve Resolution***
  - ***Materials to improve LWR***
  - ***Materials to improve Sensitivity***
- ***Combination of materials***
- ***Multi-layer stack for EUV resist***
- ***Summary***

Critical requirement of EUV resist

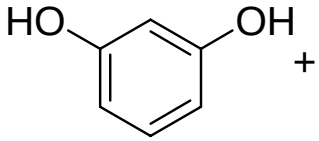


The most difficult technical requirement for EUV resist is simultaneous improvement in resolution, LWR, and sensitivity (RLS).

Many research groups are developing new materials to achieve these simultaneously

In this study, materials that can break the trade-off relationship between RLS were investigated.

Low molecular weight compound
-Material to improve resolution-

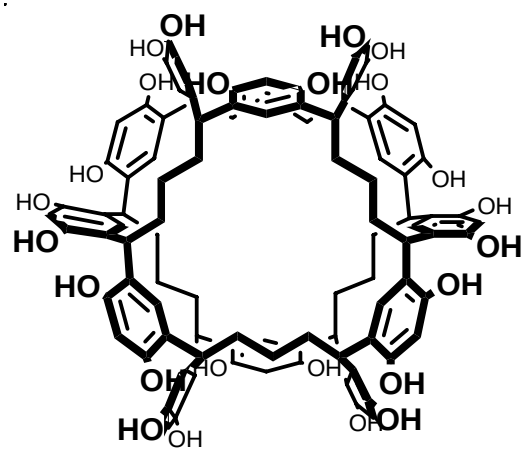


Resorcinol

+ $OHC-CH_2CH_2CH_2-CHO$

1,5- Pentanedial

$\xrightarrow[\text{80 }^{o}\text{C, 48 h in Ethanol}]{\text{HCl}}$



NORIA

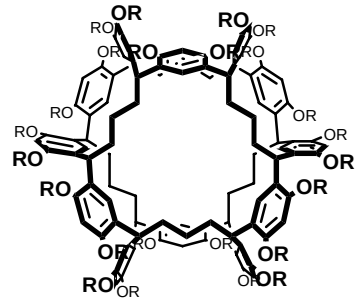
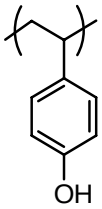
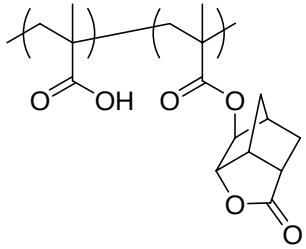
Prof. Nisikubo developed molecular glass, NORIA.

Nisikubo *et al*., *Angew. Chem. Int. Ed*. 2006, *45*, 7948-7952

- ***NORIA has shown high thermal stability with its unique structure***
- ***Resist evaluation using NORIA as a low molecular weight compound was investigated.***

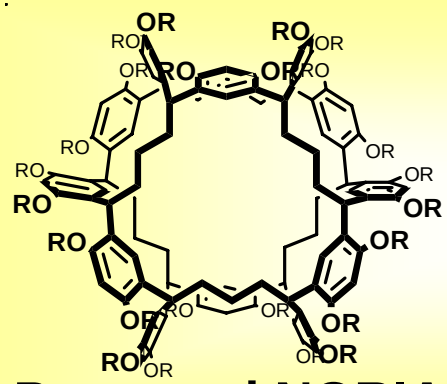
Low molecular weight compound
-Material to improve resolution-

Table. Properties of NORIA

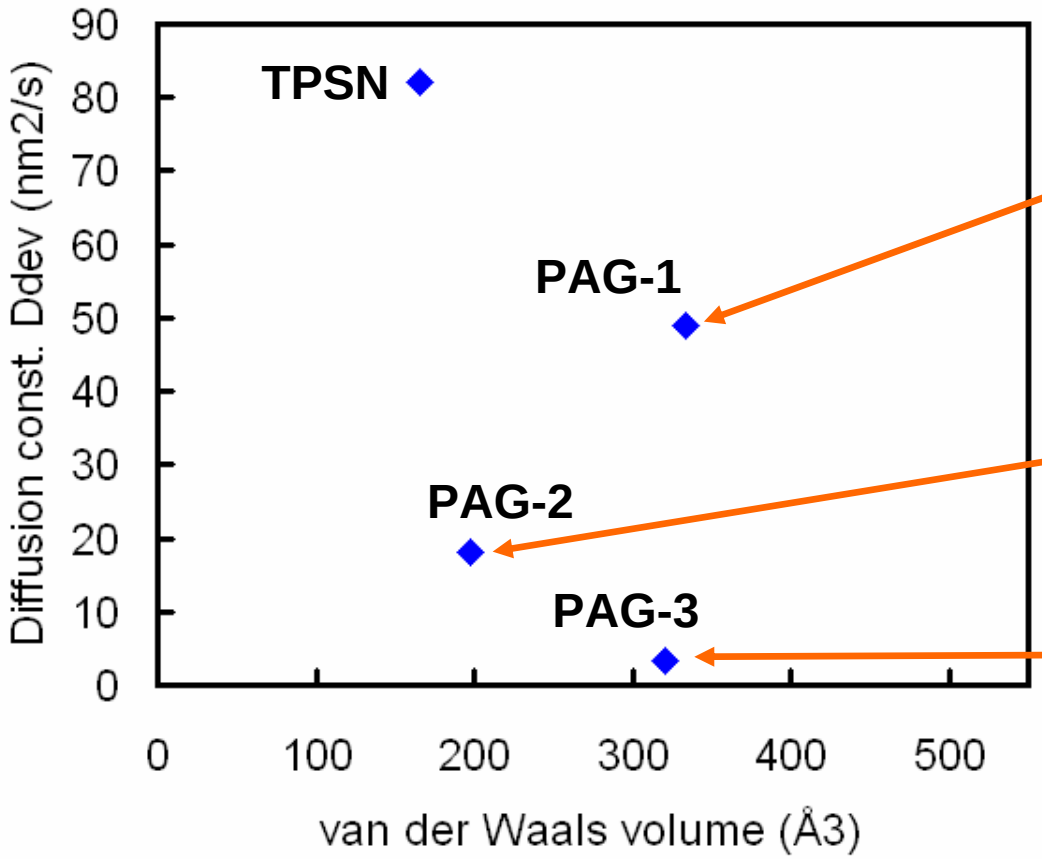
	NORIA (De-protected NORIA)	Poly (hydroxystyrene)	Poly[(methacrylic acid)-co-(lactone)]
Structure			
Molecular size (Calculate by MD)	**Approx. 2 nm**	**Approx. 5-7 nm**	**Approx. 5-7 nm**
Dissolution rate (Relative value)	**10**	**<0.1**	**1**

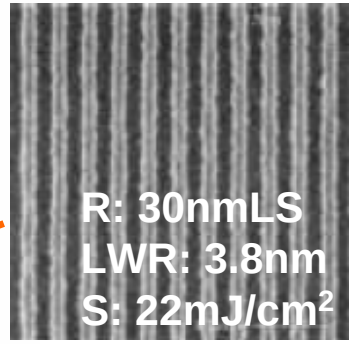
- ***NORIA showed higher dissolution rate.***
- ***NORIA possesses good properties to show high resolution***

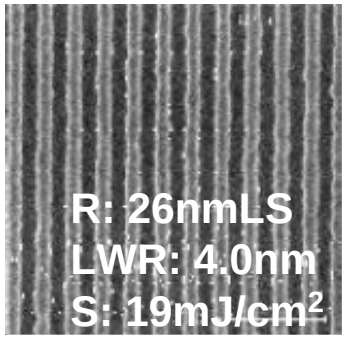
Low molecular weight compound -Material to improve resolution-

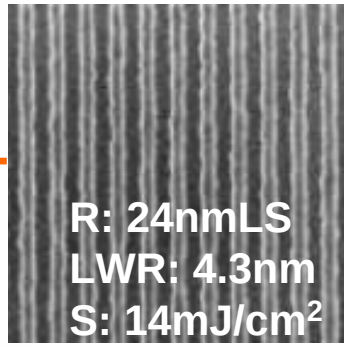

OR
RO
OR
RO
OR
RO

Acid diffusion control
- Material to improve Resolution-



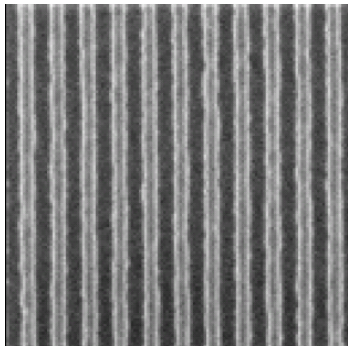
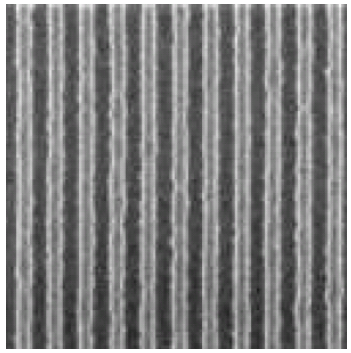






➢ ***Short acid diffusion PAG improved RLS balance, especially for resolution.***

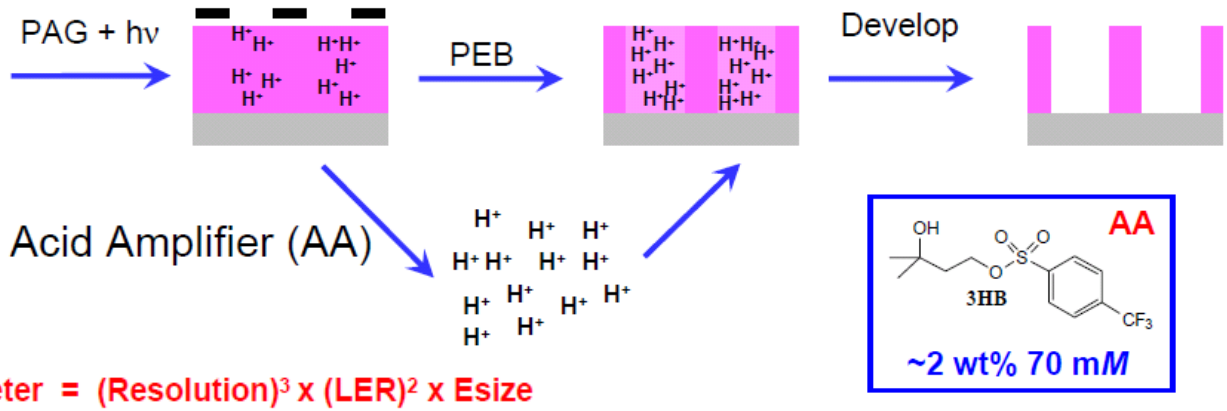
Special rinse
-Material to improve LWR-

	Special rinse process	Normal rinse process
Profile (30nm hp)		
Resolution	26nm hp	26nm hp
LWR (@30nm hp)	3.1nm	3.9nm
Sensitivity (@30nm hp)	23.5mJ/cm^2	22.3mJ/cm^2
Z-factor	3.0E-08	4.6E-08

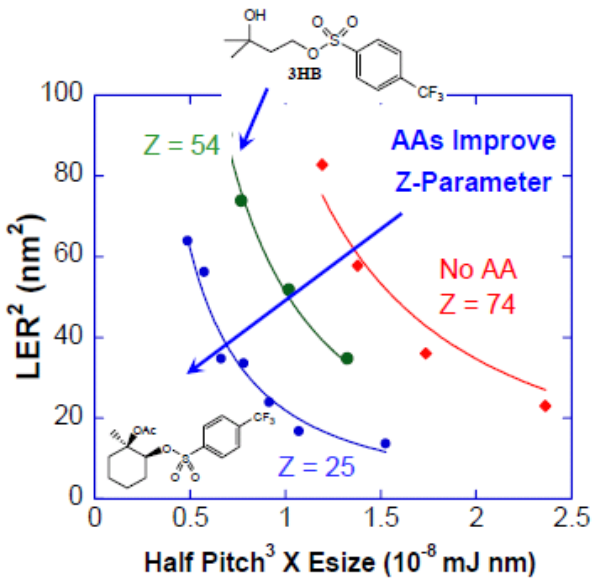
NA0.3, Quadrupole

➢ ***Special rinse process demonstrated 20 % LWR improvement.***

Acid amplifier (AA)
- Materials to improve sensitivity-



Z-Parameter = (Resolution)^3 x (LER)^2 x Esize

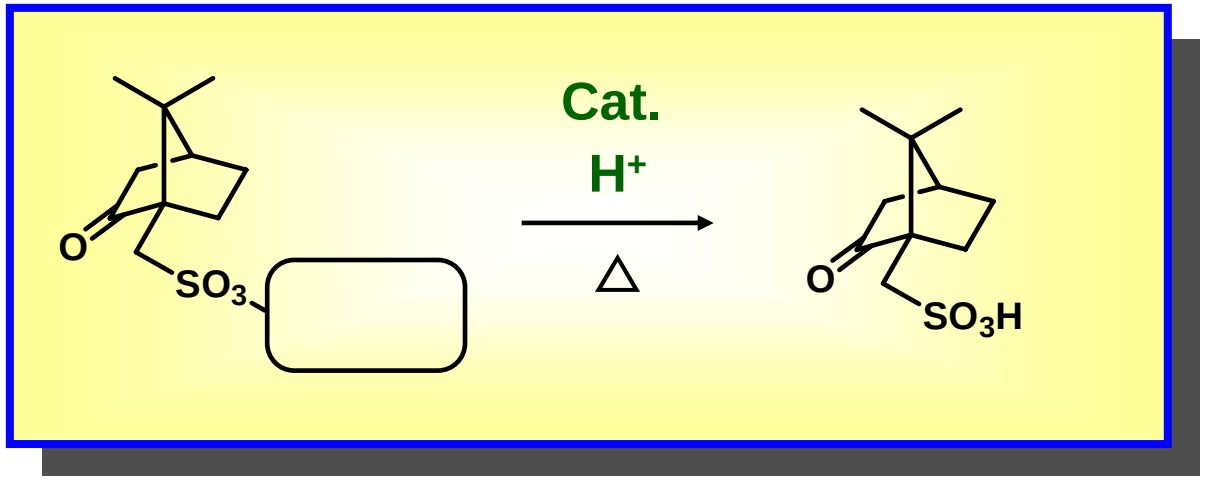


Prof. R. Brainard reported one unique way of beating RLS trade-off with the application of acid amplifier (AA).

REF: Brainard et al. 2009 International Symposium on Extreme Ultraviolet Lithography

➢ ***Given these backgrounds, we started new AA development***

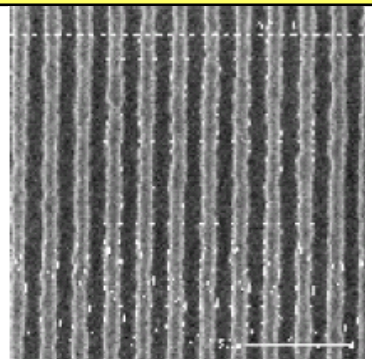
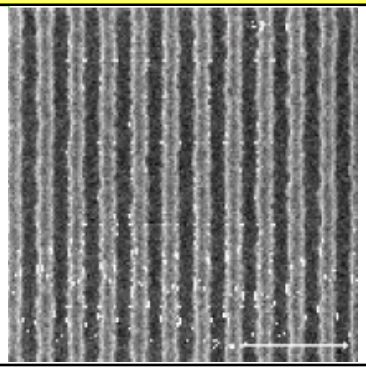
Acid amplifier (AA)
- Materials to improve sensitivity-



- ***AA generates camphorsulfonic acid by the catalysis of acid from PAG.***
- ***Development of new AA that generate strong acid is on-going***

Acid amplifier (AA)
- Materials to improve sensitivity-

NA=0.3, Quadrupole

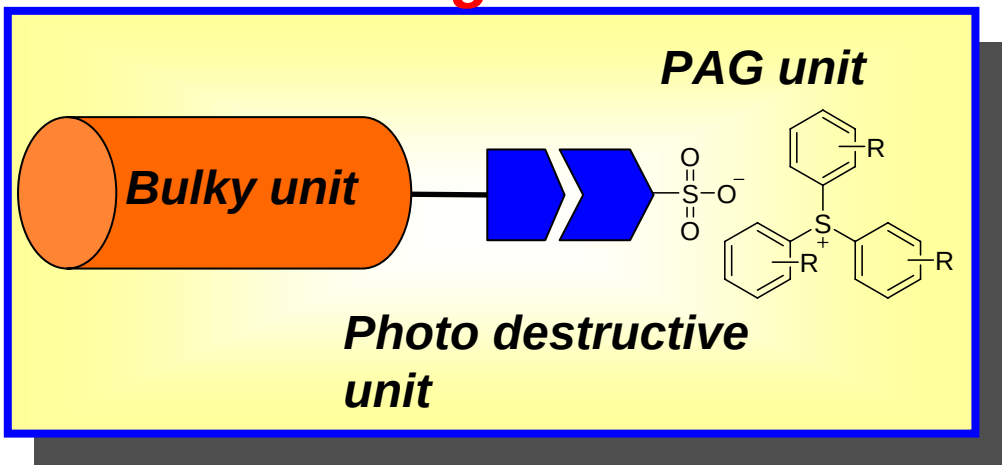
	With acid amplifier	Without acid amplifier
Profile (30nm hp)		
Resolution	24nm hp	26nm hp
LWR (@30nm hp)	5.5nm	4.7nm
Sensitivity (@30nm hp)	14.9mJ/cm^2	30.6mJ/cm^2
Z-factor*	6.1E-08	9.1E-08

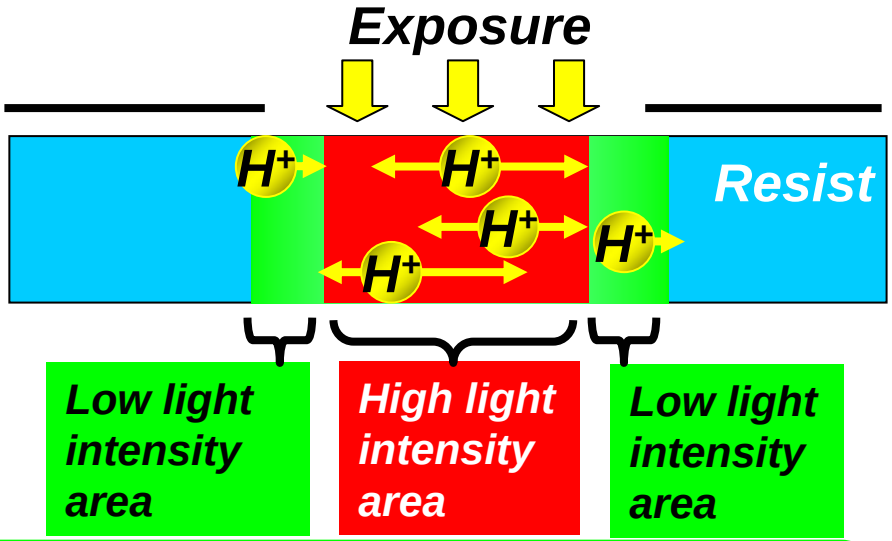
**For quantitative resist comparison, Z-factor [(mJ*nm3) = (RES)3 * (LER)2 * (SEN)] is used for benchmarking EUV resists: Wallow, T. et al Proc. SPIE 6921, 69211F (2008).*

➢ ***Acid amplifier improved Sensitivity.***

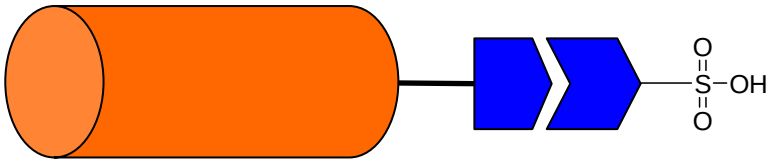
Photo destructive anion PAG (PDA-PAG) -Materials to improve sensitivity-

PDA-PAG design



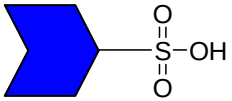


Low light intensity area



Bulky acid
- Short acid diffusion

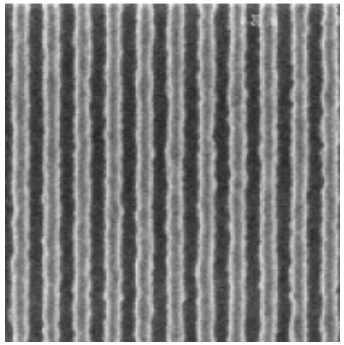
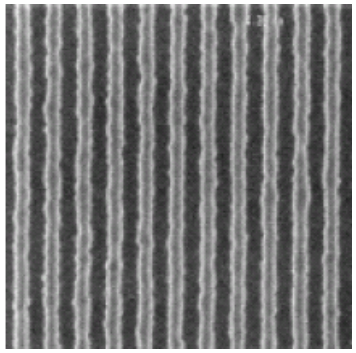
High light intensity area



Small acid
- Long acid diffusion

➢ Resist evaluation using PDA-PAG was investigated.

Photo destructive anion PAG (PDA-PAG)
-Material to improve sensitivity-

	PDA-PAG	Conventional PAG (PAG-Y)
Profile (30nm hp)		
Resolution	24nm hp	24nm hp
LWR (@30nm hp)	4.2nm	4.4nm
Sensitivity (@30nm hp)	16.7mJ/cm^2	22.4mJ/cm^2
Z-factor	4.0E-08	5.9E-08

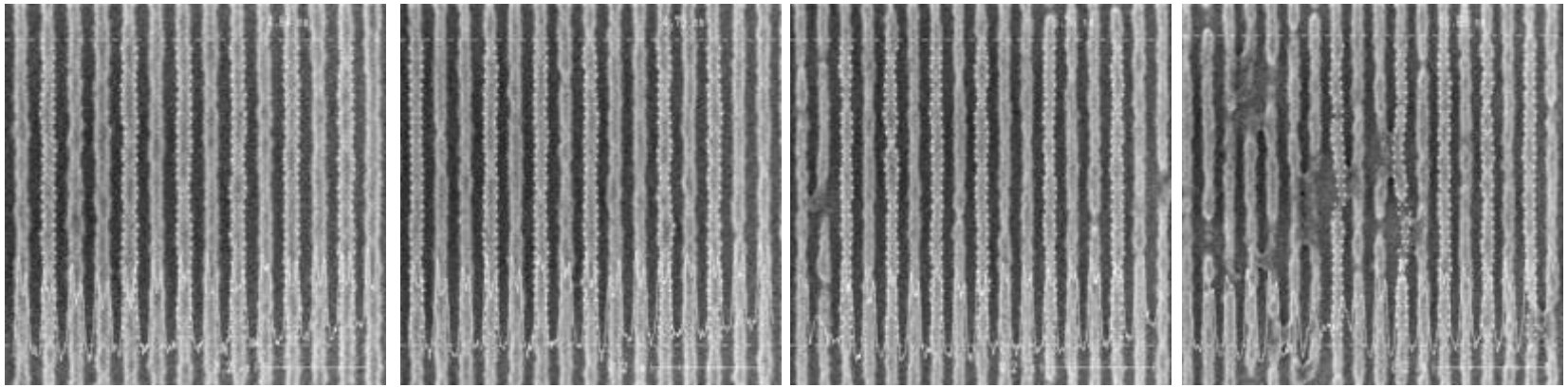
NA0.3, Quadrupole

➢ ***PDA-PAG demonstrated 25 % sensitivity improvement while keeping good resolution and LWR.***

Combination of materials

Pattern CD

24nmhp ***22nmhp*** ***20nmhp*** ***19nmhp***



NA0.3, dipole

Resolution: 20nm hp
LWR(@20nm hp): 5.8nm
Sensitivity(@20nm hp): 15.7mJ/cm^2

- ***Initial result of combination of some materials.***
- ***Further optimization with combination of materials is on-going.***

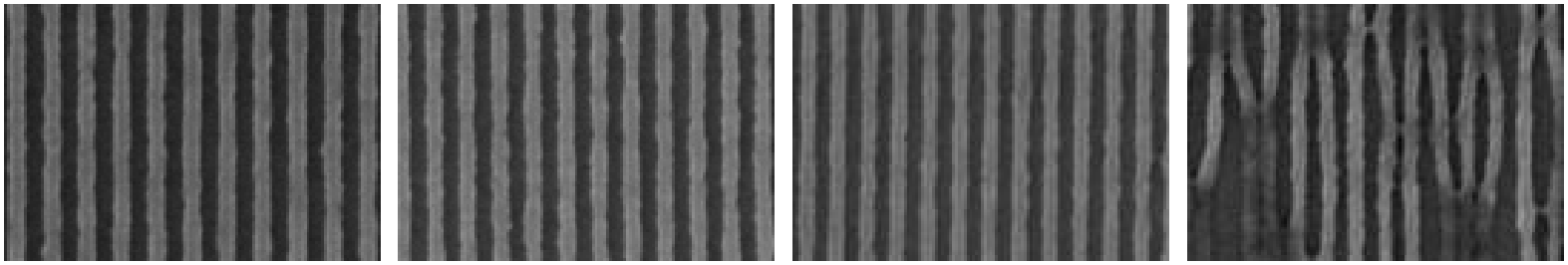
Multi-layer stack for EUV resist

Stack:

Resist 30nm
SOG 15nm
SOC 100nm

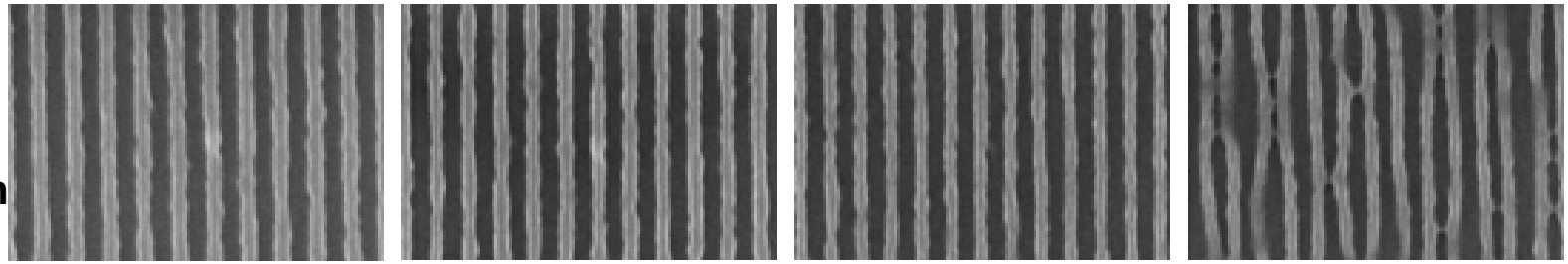
Pattern CD

30nmhp *28nmhp* *26mhp* *24nmhp*



Stack:

Resist 30nm
Org. UL 15nm



NA0.3, dipole

- ***Resist on multi-layer stack showed high performance as well as on organic under layer.***
- ***Evaluation of etching performance is on-going.***

Summary

- ***Multiple materials progress were done which would contribute to EUV resist improvement.***
  - ***Low molecular weight compound and Acid diffusion control improved resolution***
  - ***Special rinse improved LWR***
  - ***Acid amplifier and PDA-PAG improved sensitivity***

- ***Resist on multi-layer stack showed high performance.***

- ***Results of this study will push EUV technology for practical application from the resist requirement point of view.***