Characterizing polymer bound PAG type EUV resist

Shinji Tarutani, Hiroshi Tamaoki , Hideaki Tsubaki and Toshiya Takahashi

Research & Development management headquarters, Electronic Materials Research Laboratories,

FUJIFILM Corporation

Outline

1. Objective
2. Verification of the concepts
3. EUV lithographic performances
4. Summary

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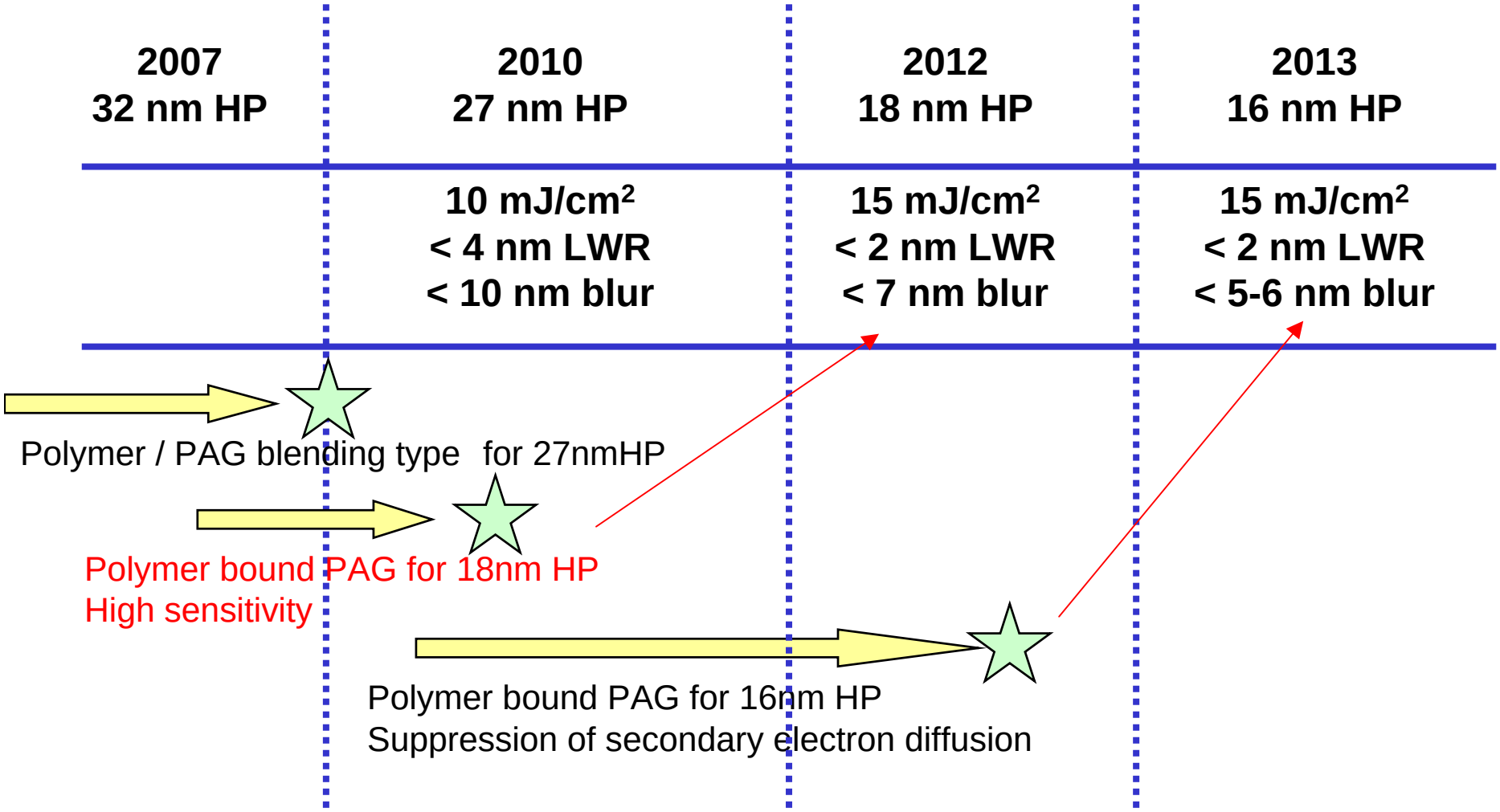
1-1. Fujifilm EUV Development roadmap



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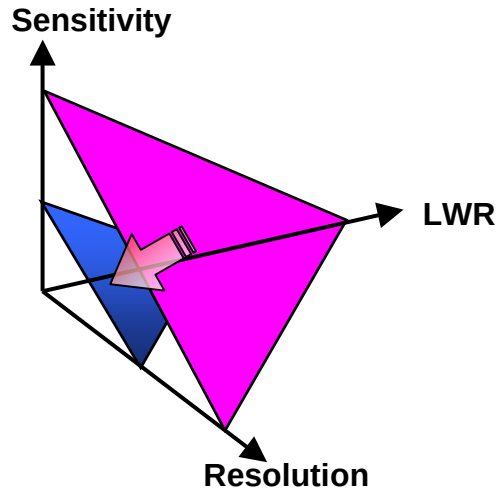
1-2. Design Policy to overcome RLS Trade-offs

	Issues*	PAG / polymer blending type	Polymer bound PAG (Anion)	Polymer bound PAG (Cation)	Molecular resist
Material uniformity	L	X	X	X	O
Distribution uniformity in film	L	X	O	O	O
Acid generation uniformity	L	X	O	O	O
De-protection uniformity	L	X	O	X	X
Development uniformity	L	O	O	O	O
Secondary electron generation	S	O	O	O	O
Secondary electron diffusion	R, L	?	?	?	?
Acid generation	S	O	O	O	O
Acid diffusion	R, L	X	O	X	X
Dissolution unit size	R, L	X	X	X	O

* : R=resolution, L=LWR, S=sensitivity



Best score was obtained with polymer bound PAG (anion) type and molecular type.

Molecular resist type has most critical risk in acid diffusion.

Polymer bound PAG (PBP) should be the best solution to control acid diffusion.

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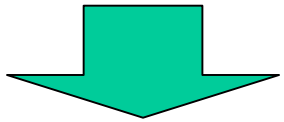
1-3. Objective

Can Polymer bound PAG break through the RLS Trade-offs?

- What are the advantages?
- Are the concepts realized?

Expectation in polymer bound PAG

Minimized acid diffusion length to affords better resolution



Is the acid diffusion really minimized ?

Resolution ?

LWR ?

Sensitivity ?

Compare to polymer and PAG blending type

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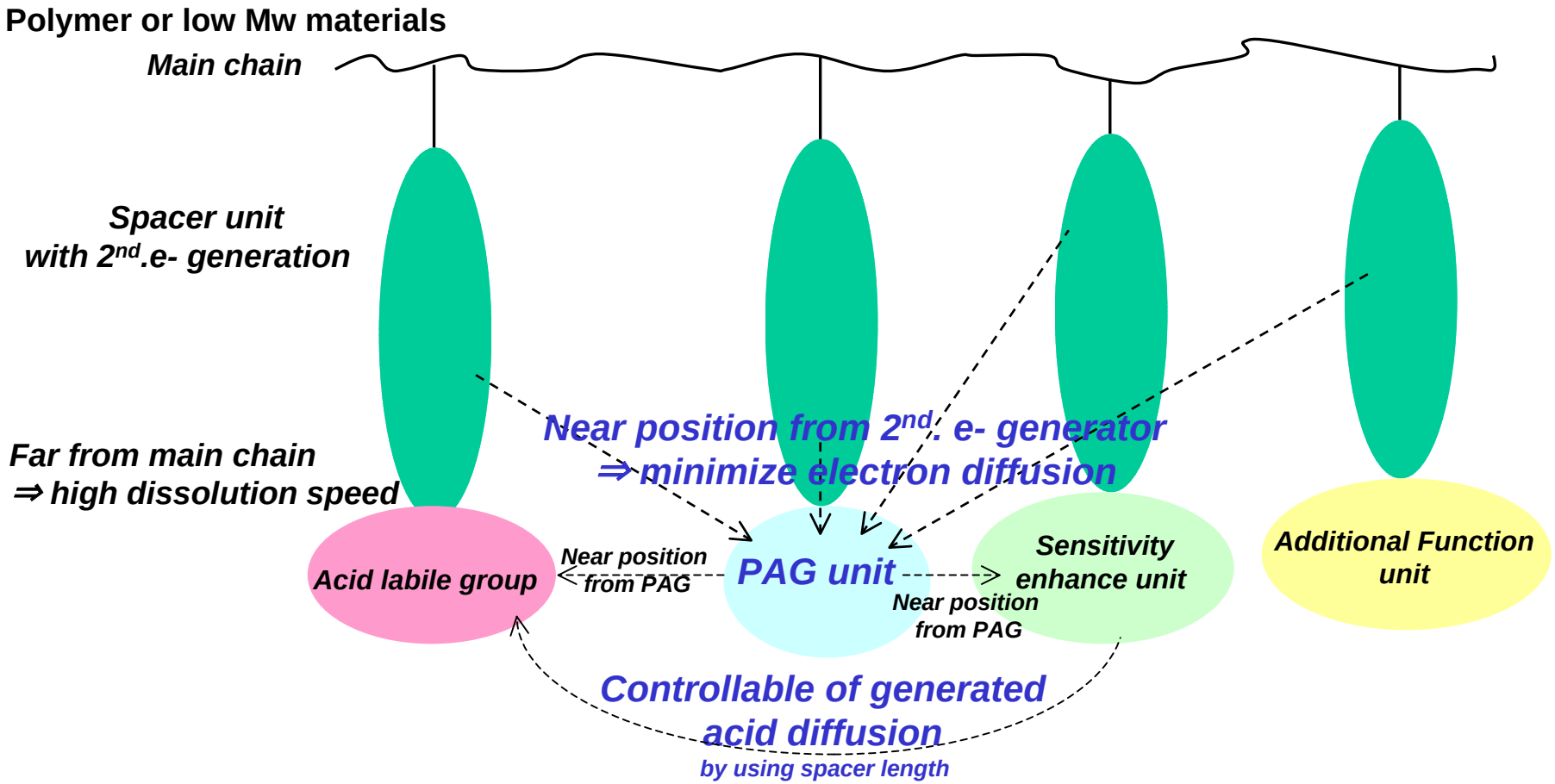
1-4. Polymer bound PAG Materials for EUV lithography

One molecular compound or polymer with all concept unit

Advantage : Possible to uniform the alkali solubility unit in film.
Possible to locate near position of PAG unit with 2ndary electron generation unit.
Possible to control of generated acid diffusion.
No concerning about miscibility of each compounds.



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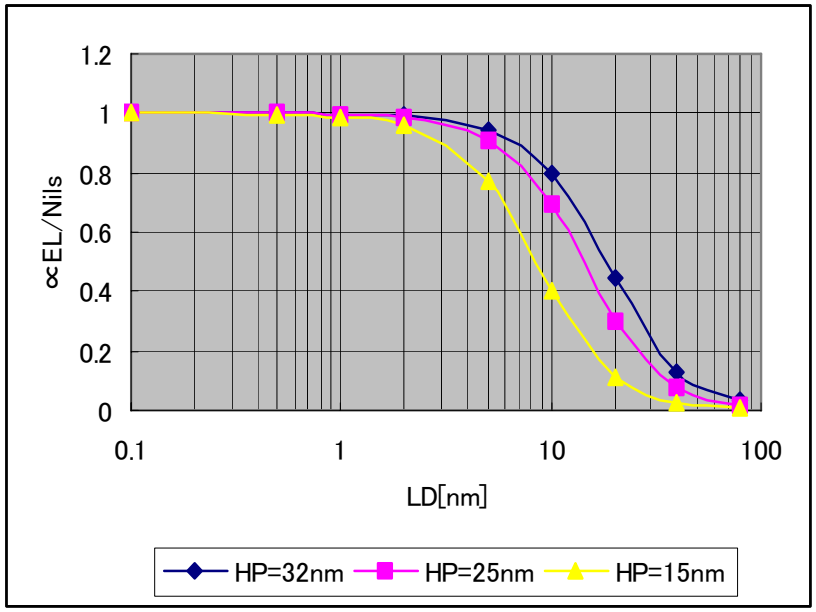
2-1. Motivation

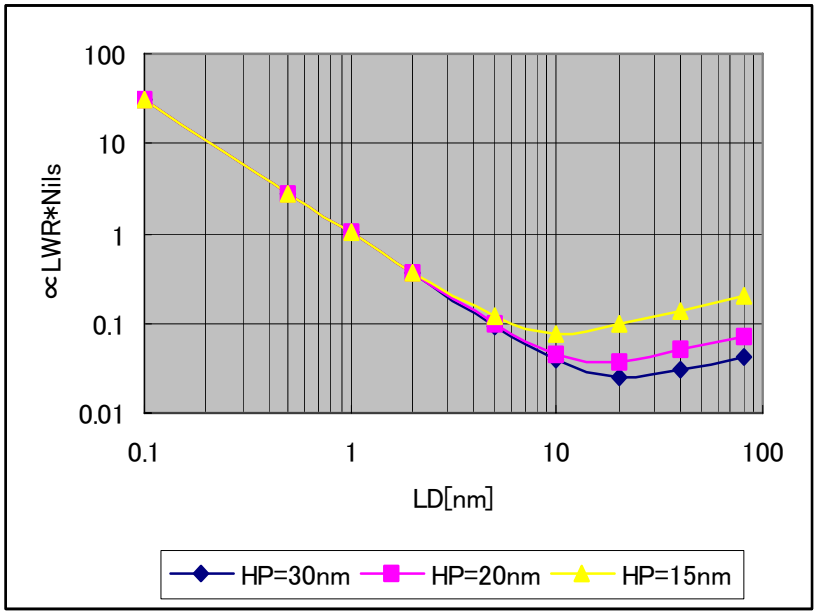
Optimal diffusion length moving toward shorter as narrowing pitch.
About 10nm diffusion length is required at EUV generation (HP=15-20nm).

$$LWR_{corr\_dose} \propto \frac{\left(1/L_D\right)^{2/3}}{NILS \bullet MTF_{diff}} \qquad LWR_{corr\_dose} = LWR * \sqrt{\frac{Dose}{h\nu \bullet d}}$$

MTF_{diff}: Modulation transfer function due to diffusion
Ld: Diffusion length of acid, p: pitch, d: Resist thickness

D. Van Steenwinckel, et al, Proc. SPIE, 5753, 269 (2005). , D. Van Steenwinckel, et al, J. Vac. Sci. Technol. B, 24, 316 (2006).





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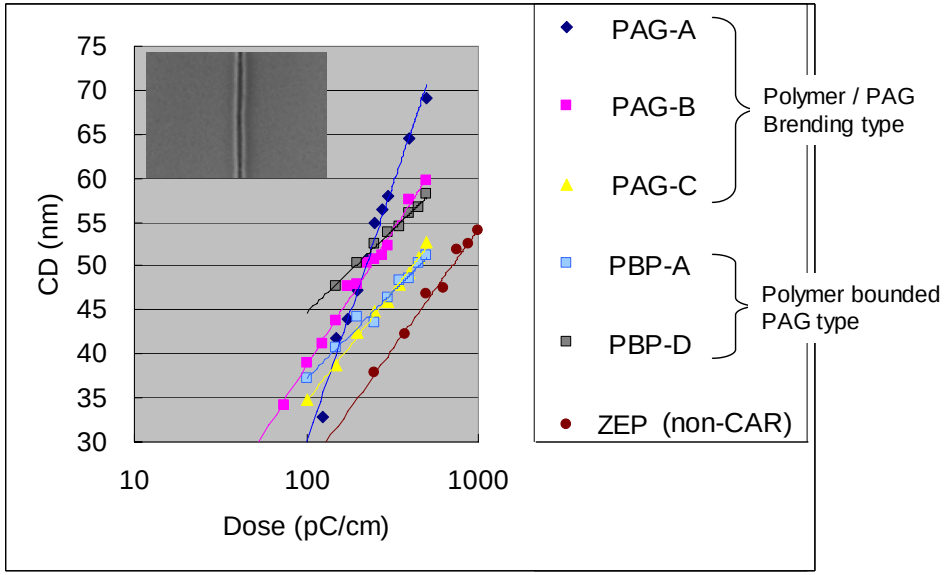
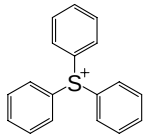
2-2. Acid diffusion length

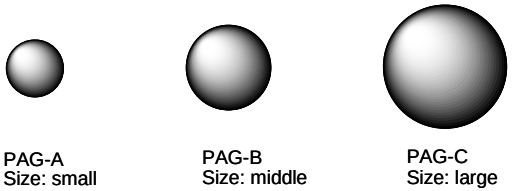
Acid diffusion length is evaluated from isoline CD of EB lithography.



Cation : TPS



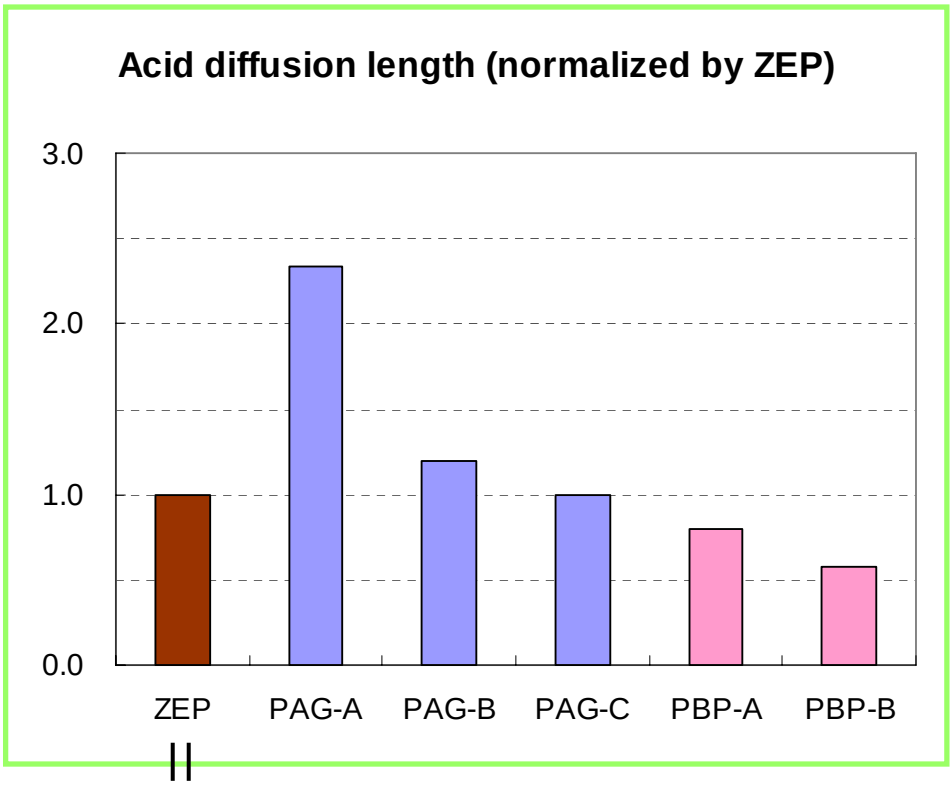
Anion size



PAG-A
Size: small

PAG-B
Size: middle

PAG-C
Size: large



Electron diffusion only

Acid diffusion length of polymer bound PAG type is shorter than that of blend type.

Futhermore, polymer bound PAG type can trap 2ndary electron in nearest position.

(Its electron diffusion length is evaluated shorter than that of ZEP.)

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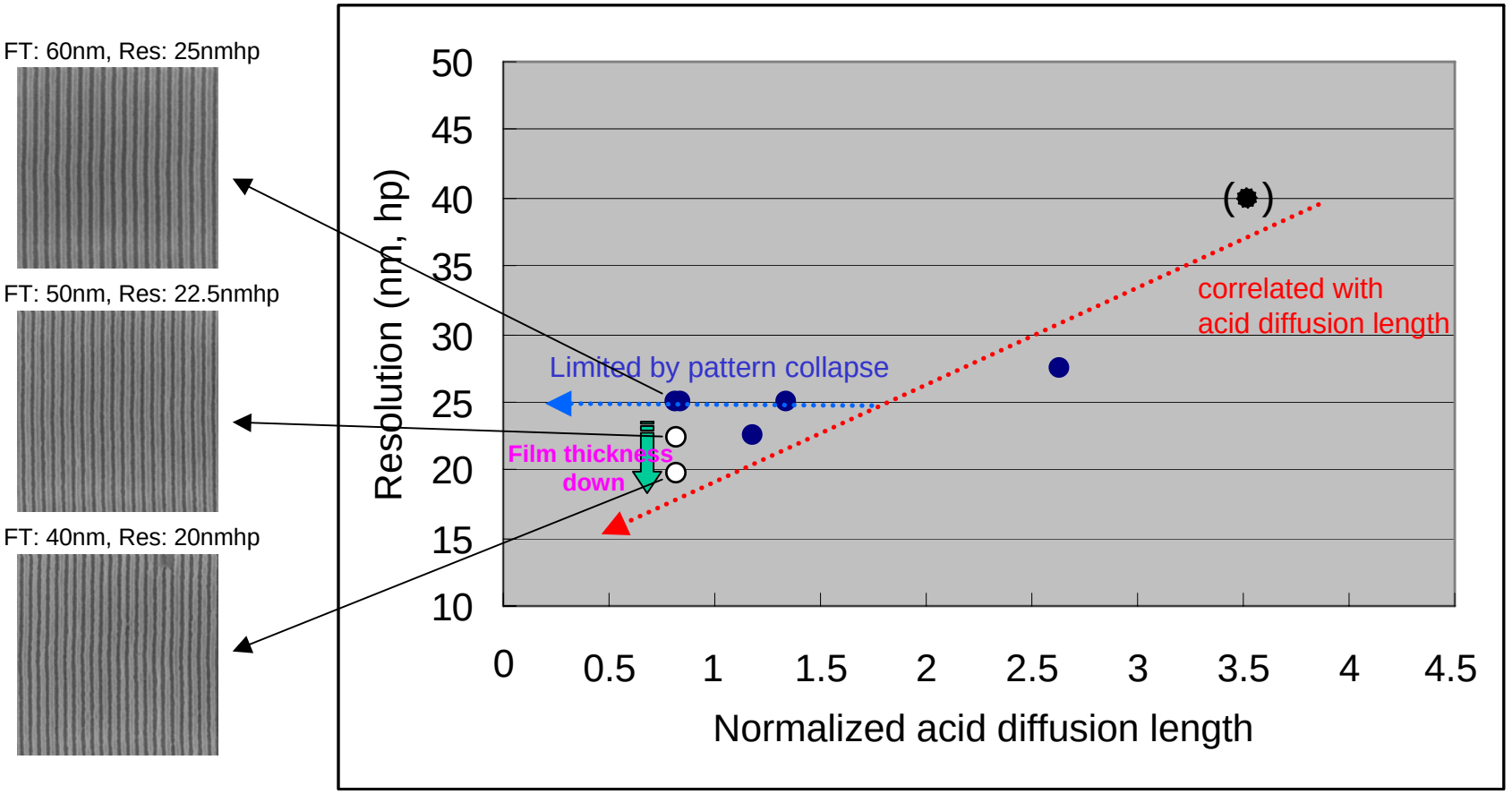
2-3. Resolution Capability

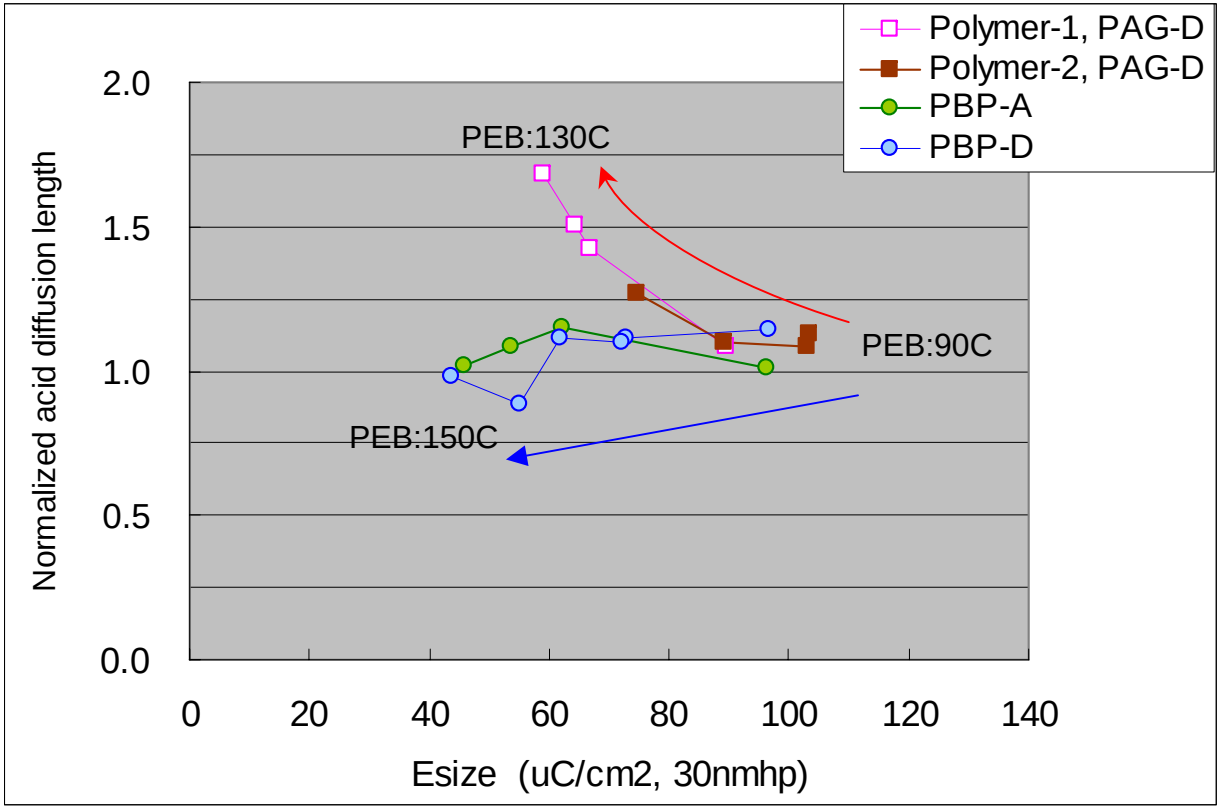
EB lithography



Resolution is improved as acid diffusion length becomes shorter, if there is not another issues such as pattern collapse.

2-4. Overcoming the Resolution and Sensitivity trade-off

PEBs is compared between polymer bound PAG type and blend type. EB lithography



PAG-D is larger than PAG-C

On high temperature PEB process, polymer bound PAG type supports high sensitivity and short acid diffusion length(=high resolution), but blend type does not.

Polymer bound PAG type can break through the Resolution-Sensitivity trade-off.

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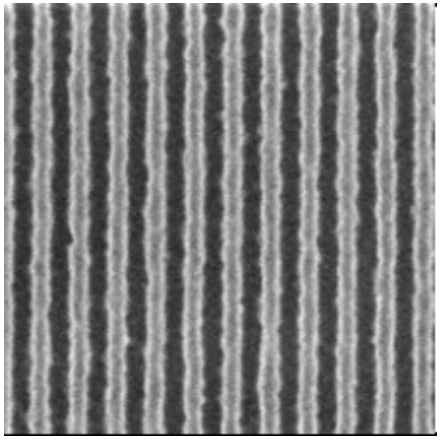
3-1. EUV lithographic performances

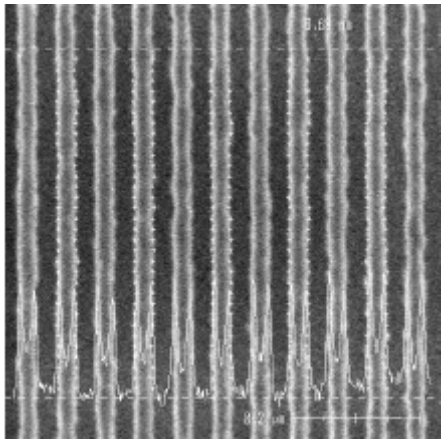
30nm hp L/S

Polymer/PAG blend type
(Polymer-3, PAG-D)



Esize = 13.9mJ/cm2
Min LWR = 4.6nm
DOF < 50nm

Polymer bound PAG type
(PBP-E)



Esize = 15.9mJ/cm2
Min LWR = 3.7nm
DOF = 350nm

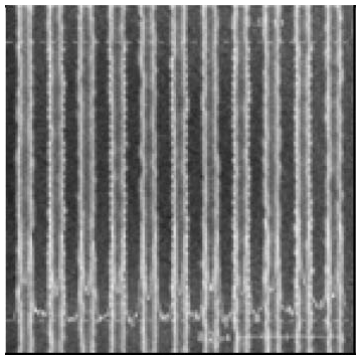
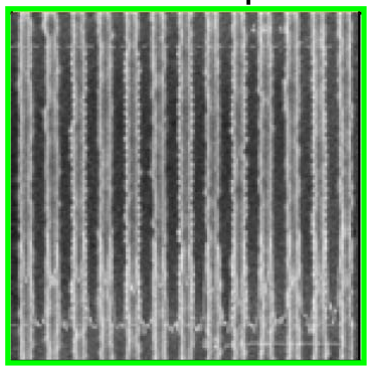
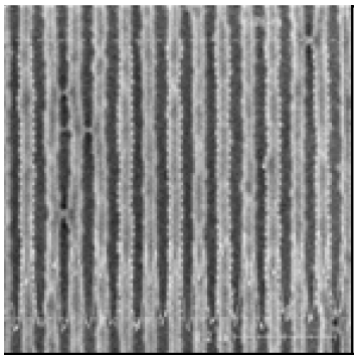
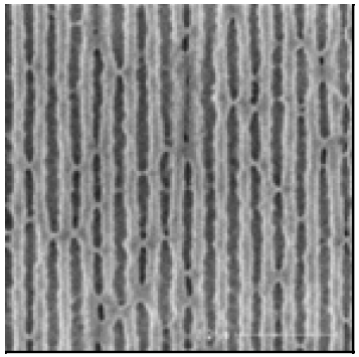
Tool : MET
Illumination : Quadrupole (0.68/0.36)
Substrate : Si/UL

Polymer bound PAG type(PBP-E) showed very small LER and wide DOF.

This result indicates that acid diffusion length is successfully controlled by polymer bound PAG.

3-2. EUV lithographic performances

Polymer bound PAG type(PBP-E) ultimate resolution

30nm hp	26nm hp	24nm hp	22nm hp
			
CD = 28.6nm LWR = 3.7nm	CD = 25.6nm LWR = 4.4nm	CD = 24.9nm LWR = 6.1nm	CD = ---nm LWR = ---nm

Ultimate resolution = 26nm, limited by micro bridging and pattern collapse.

But, pattern is formed and separated on 22nm hp.
It is assumed that polymer bound PAG has enough potential to resolute 22nm hp or more.

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4. Summary

1. Acid diffusion length of polymer bound PAG type is shorter than that of polymer/PAG blend type (and ZEP).

2. Polymer bound PAG type supports high sensitivity and high resolution.

3. Polymer bound PAG type showed very small LWR and wide DOF on EUV lithography evaluation.