Development of Novel molecular glass resists for EUVL

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Concept for our EUV resist

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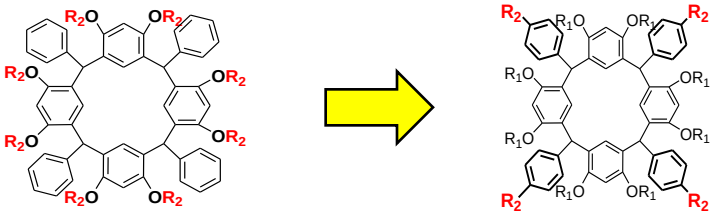
Concept and Previous Work

- **We had developed tetraphenylcalix[4]-resorcinarene (CLM-M) and other CLM-resists.**
- **CLM-resists is good performance for EUV resist.**

- **The CLM-resist performance with mono disperse number of protecting group(PG) is more excellent than that of the one with wide disperse number of PG.**



R_2 : protecting group or H　　R_2 : protecting group

<Proc.of SPIE, Vol.7273,72732R-1, (2009)>

- **Relationship of the PG structure with resolution capability, thermal stability etc.**
  Adamantane-based type PG is the best performance for EUV exposure.

<2010 International Symposium on Extreme Ultraviolet Lithography >

- **High polar material blend is effective method for the improvement of pattern collapse.**

<2011 International Symposium on Extreme Ultraviolet Lithography >

- **Further improvement of the resist performance**

We have synthesized PAG-bound CLM-resist in order to improve the uniformity of the resist film and evaluated the resolution capability by EB and EUV exposure experiment.

Previous Work : Effect of Molecular Weight Distribution

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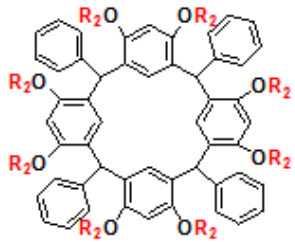
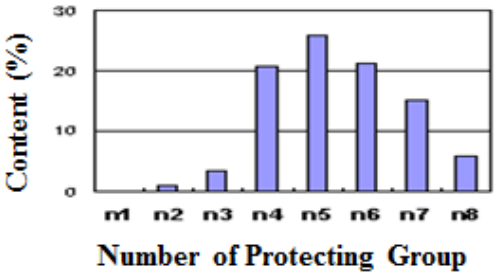
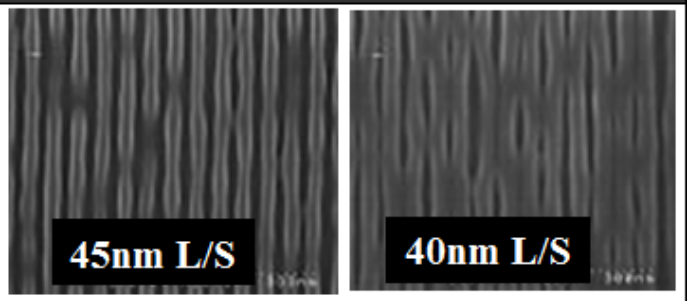
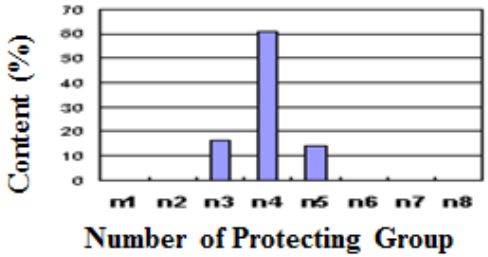
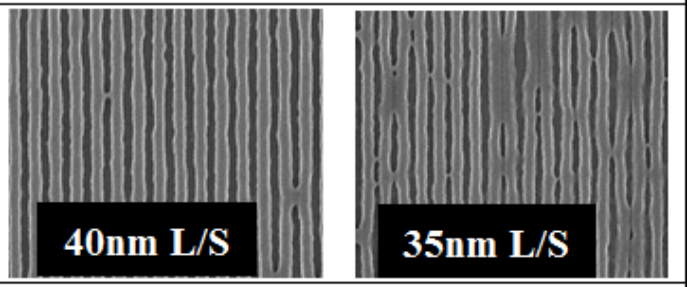
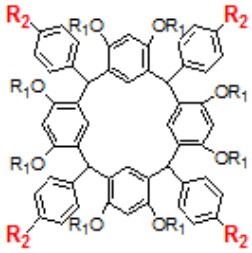
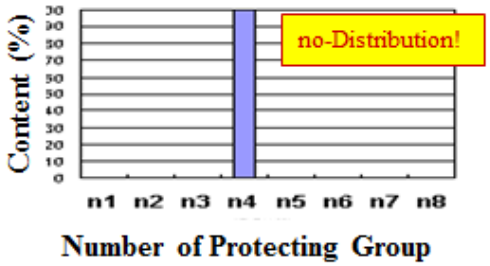
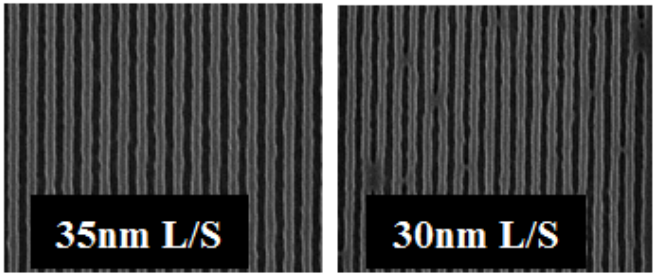
Structure	Distribution of molecular weight (Number of protecting group)	SEM image (EB 50keV)
 R_2 : protecting group or H		
		
 R_2 : protecting group		

- The resolution capability was improved by reducing the distribution of the number of protecting groups.
- The uniformity of the chemical reactivity between resist material and H^+ is important for improvement of the resolution.

Previous Work : Effect of PG Structure

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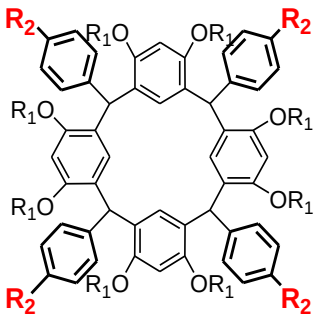
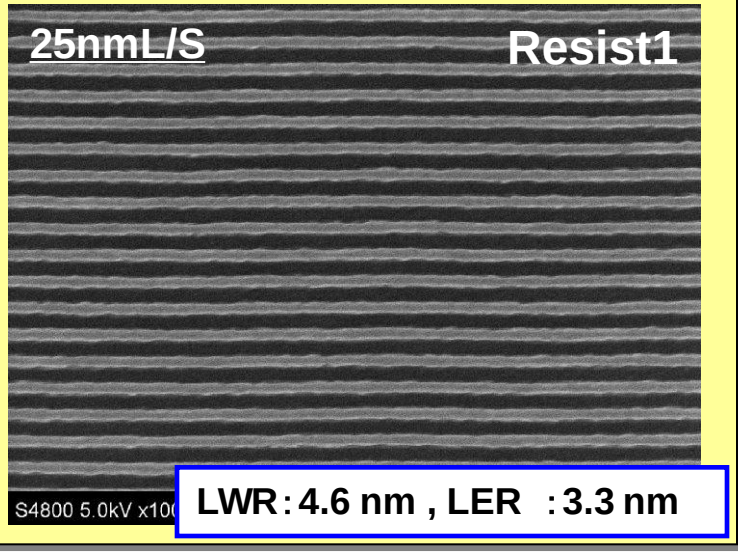


R_1 : Substituent or H
R_2 : Protecting Group (PG)

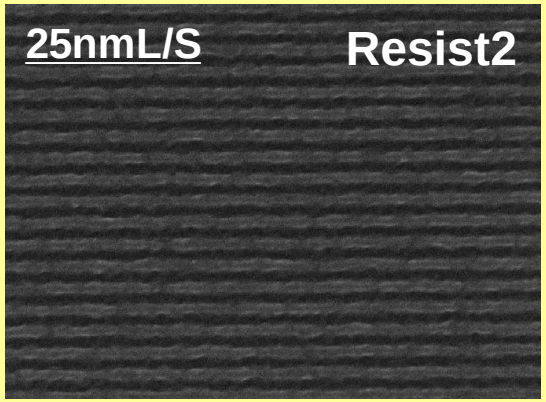
Results of EUV interference lithography @Univ. of Hyogo

R2:Adamantane-based type PG

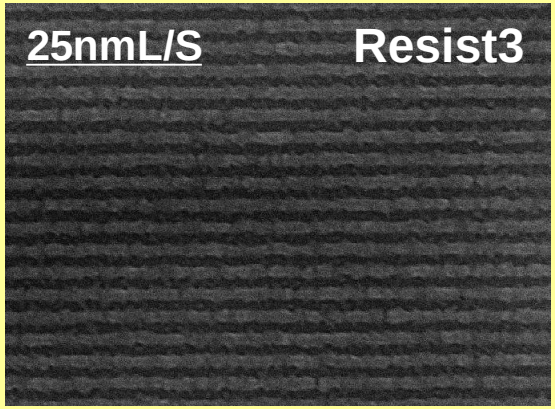


LWR : 4.6 nm , LER : 3.3 nm

R2:Cycloalkyl-based type PG



R2:Aromatic-based type PG



- **Adamantane-based type PG showed the best performance for EUV-IL.**
- **The rigid structure of PG is effective in improvement of the pattern shape because of its high heat resistance and high the film strength.**

Previous Work : Effect of High Polar Material Blend

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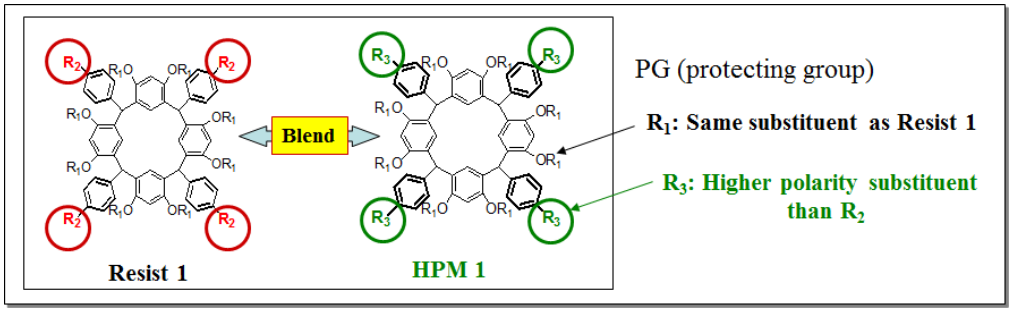
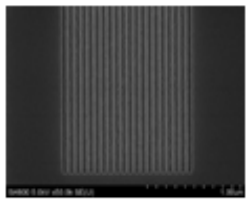
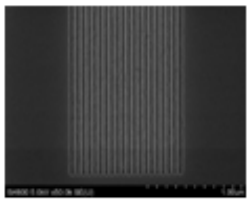
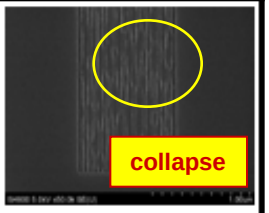
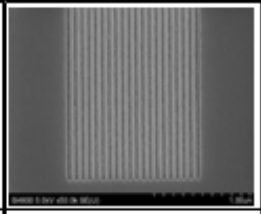
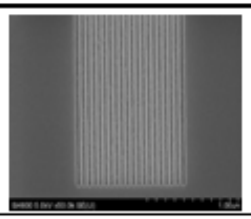
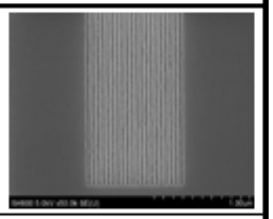
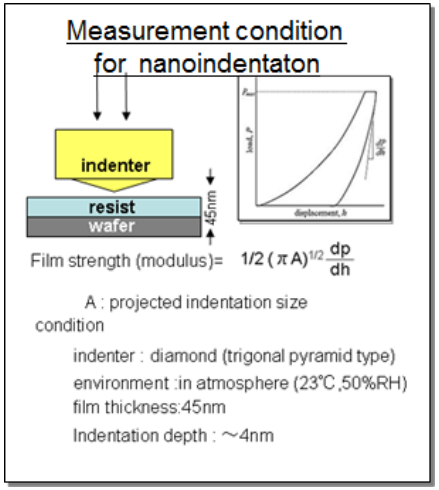


Result of nanoindentation and EB exposure experiment (50keV)

	35nmL/S	30nmL/S	25nmL/S
Resist 1			 collapse
Dose(μC/cm2)	40	40	40
Film strength (GPa)	48.9		
Resist 1+ HPM 1			
Dose(μC/cm2)	52	52	52
Film strength (GPa)	57.4		



- **The resolution property was improved by blending of the high polar material.**
- **The pattern collapse was reduced by increasing the film strength because of the interaction reinforcement between Resist 1 and the high polar material (HPM).**

Improvement of Resist Film Uniformity

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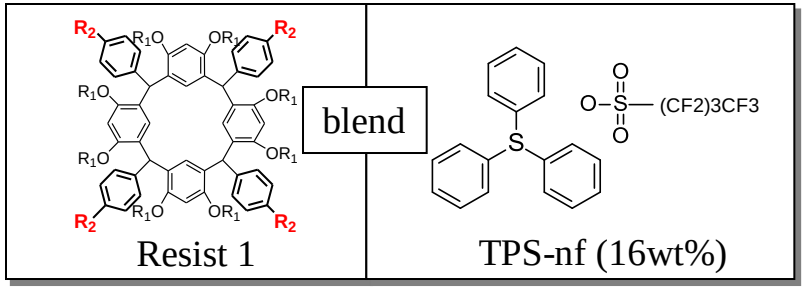
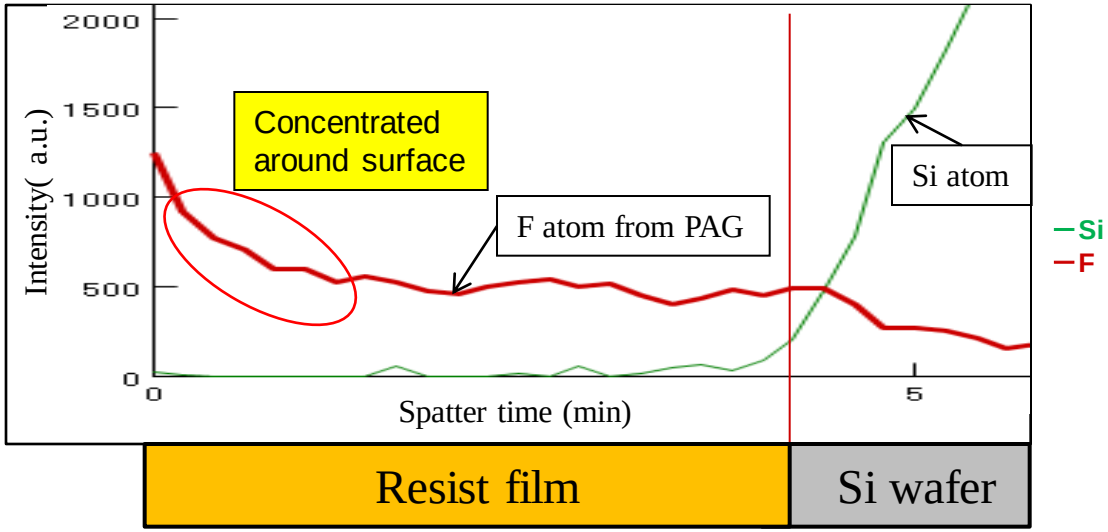
- **The dispersion uniformity of the additive (PAG, quencher …etc.) is required for the resist performance (resolution, LWR) improvement.**



Measurement of the dispersibility of F atom in "Resist 1 - TPS-nf blend" film by XPS depth profile



(F.T. 100nm)

- **TPS-nf (PAG) was unevenly distributed in the resist film, and especially concentrated around the surface.**

Improvement of Resist Film Uniformity

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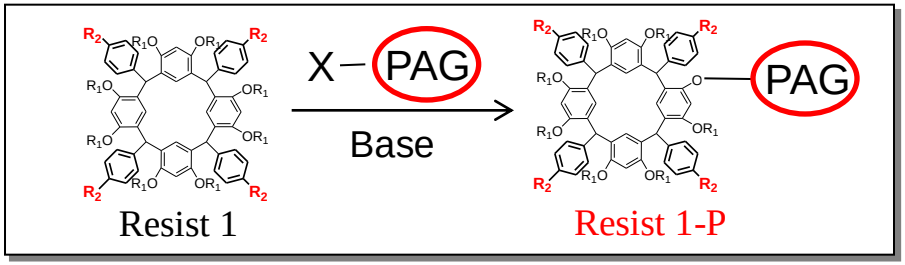
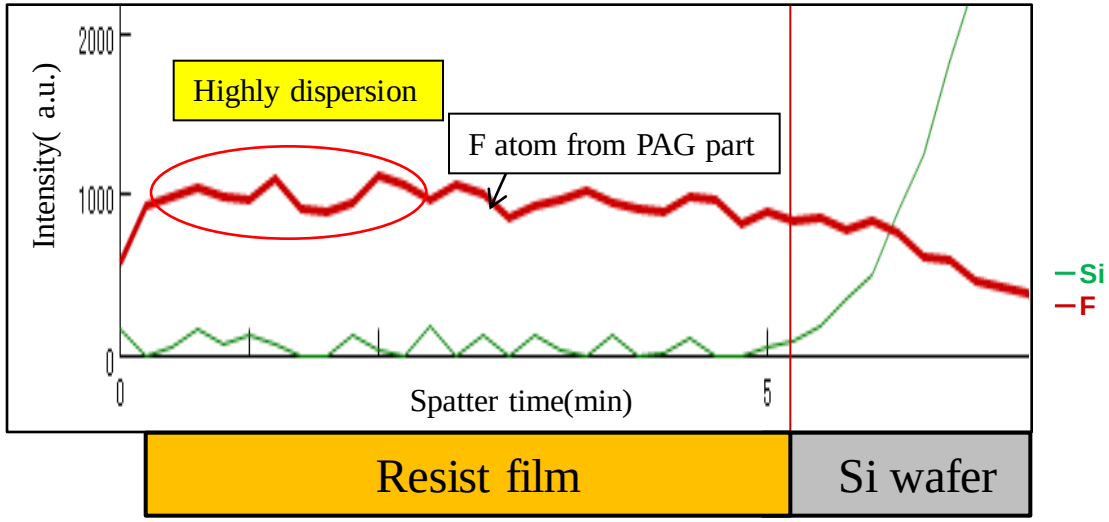
- We have synthesized PAG-bound CLM-resist (Resist 1-P) in order to improve the dispersibility of PAG in the resist film.



Measurement of the dispersibility of F atom in Resist 1-P film by XPS depth profile



(F.T. 100nm)

- PAG was highly dispersed in the Resist 1-P film.
- The improvement of resist performance is expected by using Resist 1-P.

EB exposure experiment

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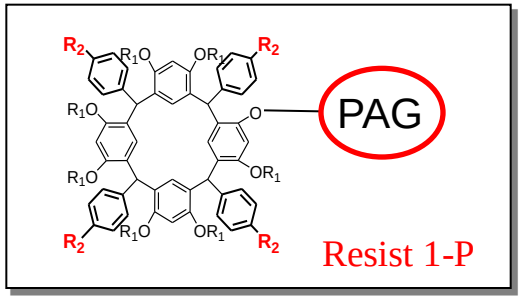
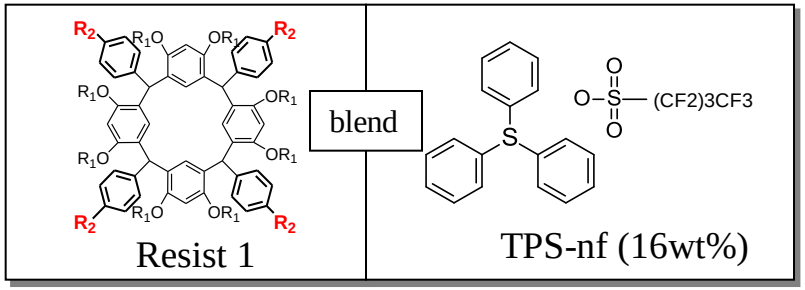
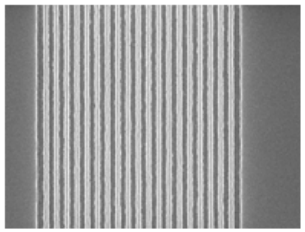
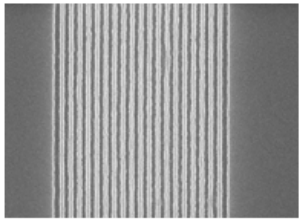
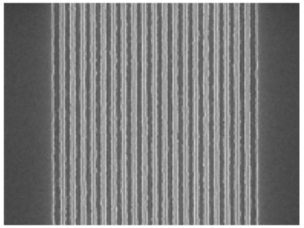
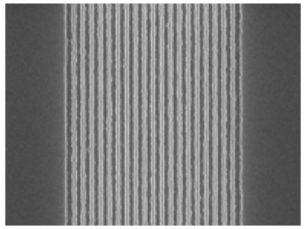




The results of EB exposure experiment (50keV)

	35nmL/S	30nmL/S
Resist 1-P		
Sensitivity	44μC/cm2	44μC/cm2
LWR	5.7nm	6.3nm
resist 1		
Sensitivity	48μC/cm2	48μC/cm2
LWR	6.5nm	6.2

- **LWR was improved by increasing the resist film uniformity by using Resist 1-P.**
- **We supposed that the other reason for the LWR improvement was the shorter acid diffusion length of Resist 1-P than that of Resist 1.**

EUV exposure experiment

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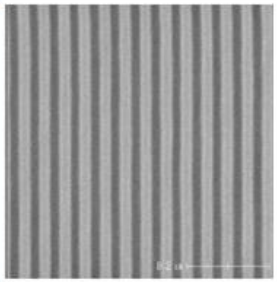
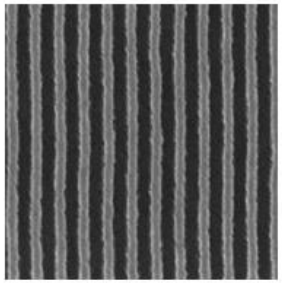
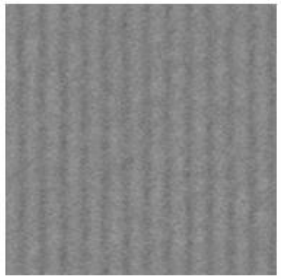
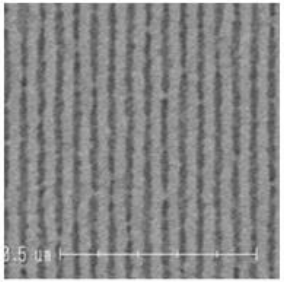
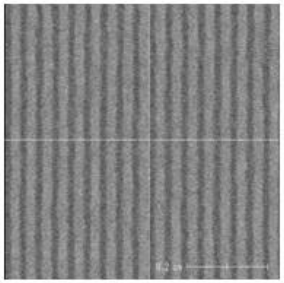
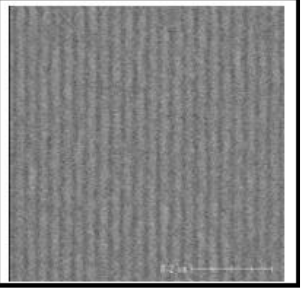
The results of EUV interference lithography @Univ. of Hyogo

	non-CAR	Resist 1	Resist 1-P
25nmL/S			
20nmL/S			
15nmL/S	—	—	

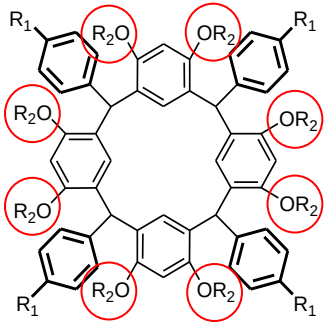
- **We have achieved 15nm hp resolution by using Resist 1-P.**

Idemitsu Kosan Co.,Ltd.

Summary

- **We have evaluated PAG-bound CLM-resist (Resist 1-P) to improve the PAG uniformity in the resist film.**
- **We have achieved 15nm hp resolution by using PAG-bound CLM-resist.**

Future Work



R_1 : Protecting Group
R_2 : Substituent or H

We are evaluating the optimization of the PAG structure of PAG-bound CLM-resist and blending high polar material for improvement resist capability (resolution, LWR ,increasing the mechanical strength of resist film)

Acknowledgments

We are deeply grateful to the cooperation of University of Hyogo about EUV IL experiments.

Thank you