



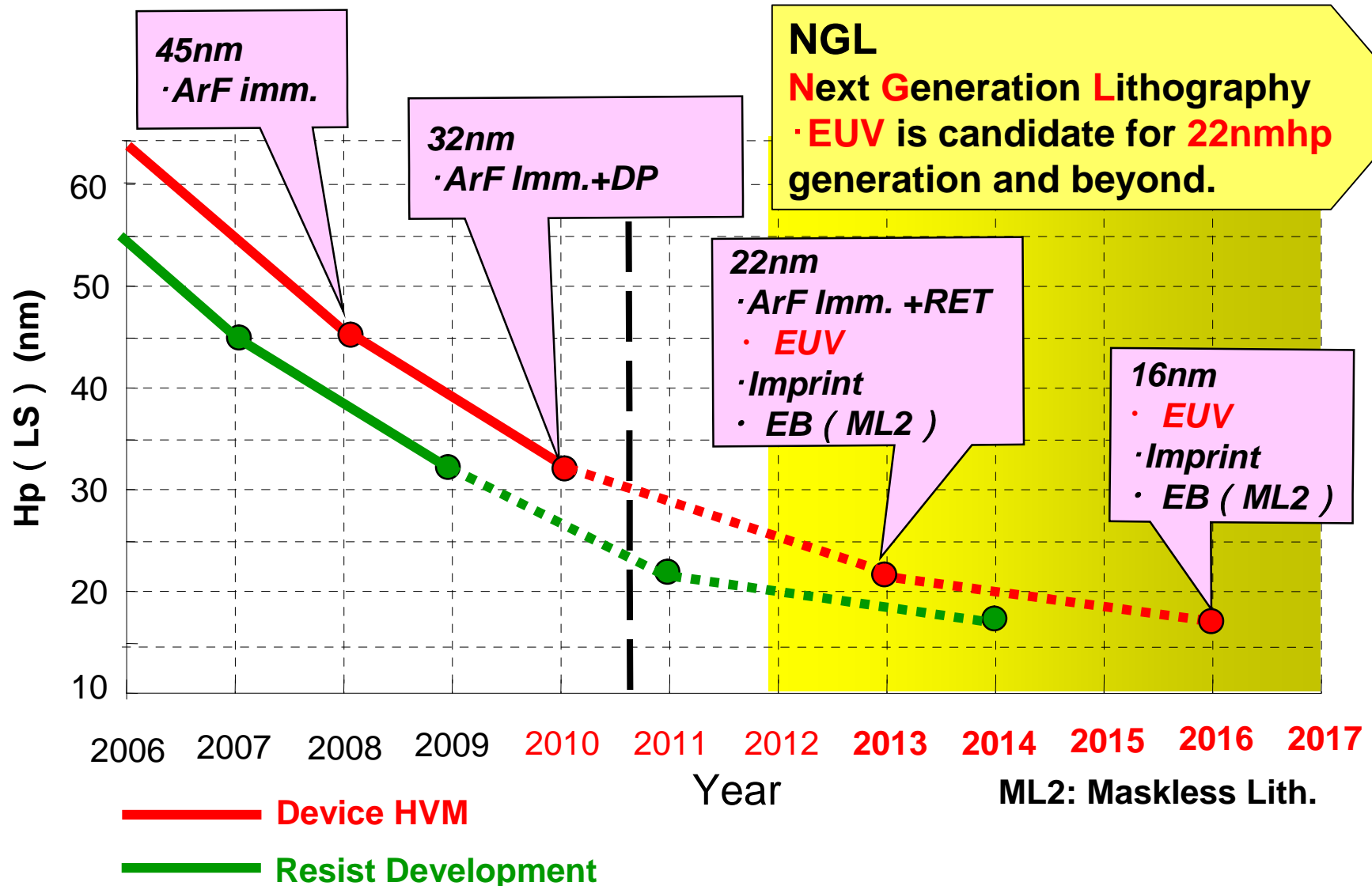
# **EUV Resist Development toward 22nmhp Design and Beyond**

*JSR Corporation*

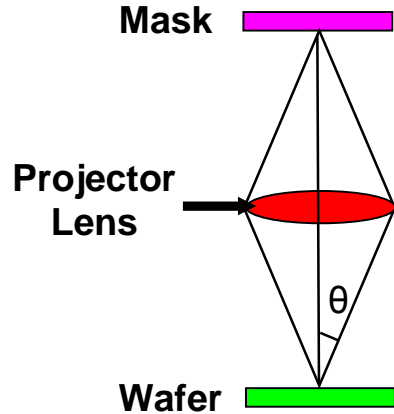
# Contents

- **Introduction**
- **RLS Balance Improvement**
  - **Low molecular weight compound**
  - **New PAG design (PDA-PAG)**
- **High Resolution Resist Development**
  - **Fluorinated polymer**
- **Summary**

# Lithography Roadmap



# EUV Technology Extendability



**Resolution**= $k_1\lambda/NA$

DOF= $k_2\lambda / ( NA )^2$

- NA= $n \cdot \sin\theta$
- n : Reflective index

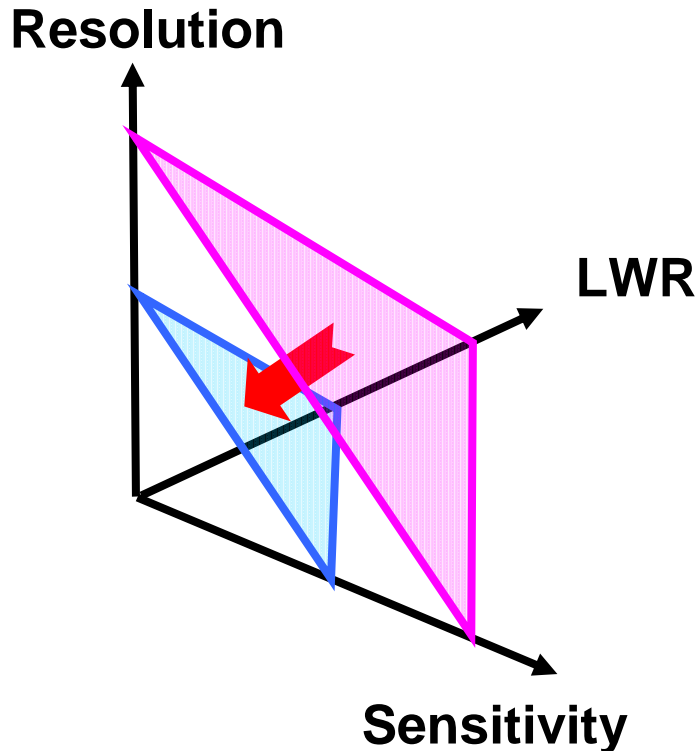
- $k_1 \cdot k_2$  : Constant (  $\geq 0.3$  needs for productivity )
- $\lambda$  : Wave length
- NA : numerical aperture

## • k1 Values comparison

	Process			Half pitch (nm)			
	$\lambda$	NA	Step	32	22	16	11
ArF Imm.	193	1.35	SE	0.22	0.15	0.11	0.08
			DP	0.45	0.31	0.22	0.15
EUV	13.5	0.25	SE	0.59	0.41	0.30	0.20
		0.35	SE	0.83	0.57	0.41	0.29
		0.50	SE	1.19	0.81	0.59	0.41

➤ EUV has capability to cover 11nmhp design.

# Critical Requirement of EUV Resist



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

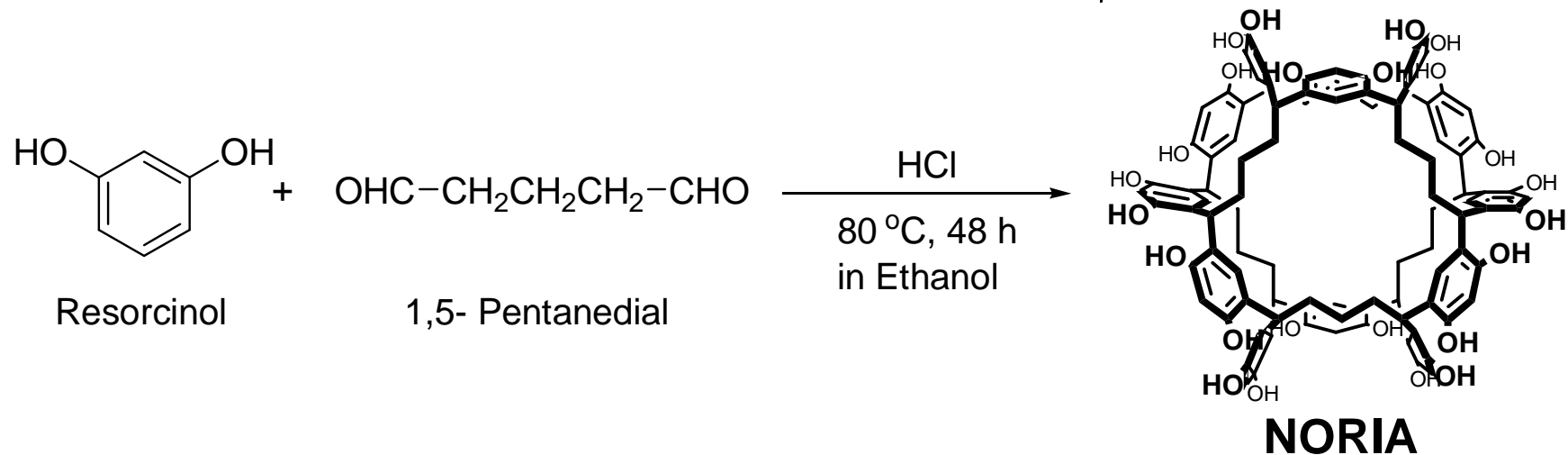
*Many research groups are developing new materials to achieve these simultaneously*

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

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# Low molecular weight compound -Material to improve resolution-



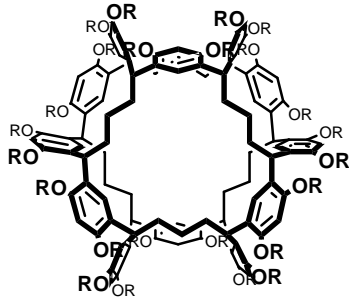
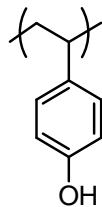
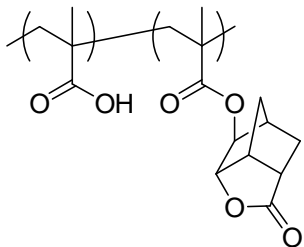
**Prof. Nisikubo developed molecular glass, *NORIA*.**

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-

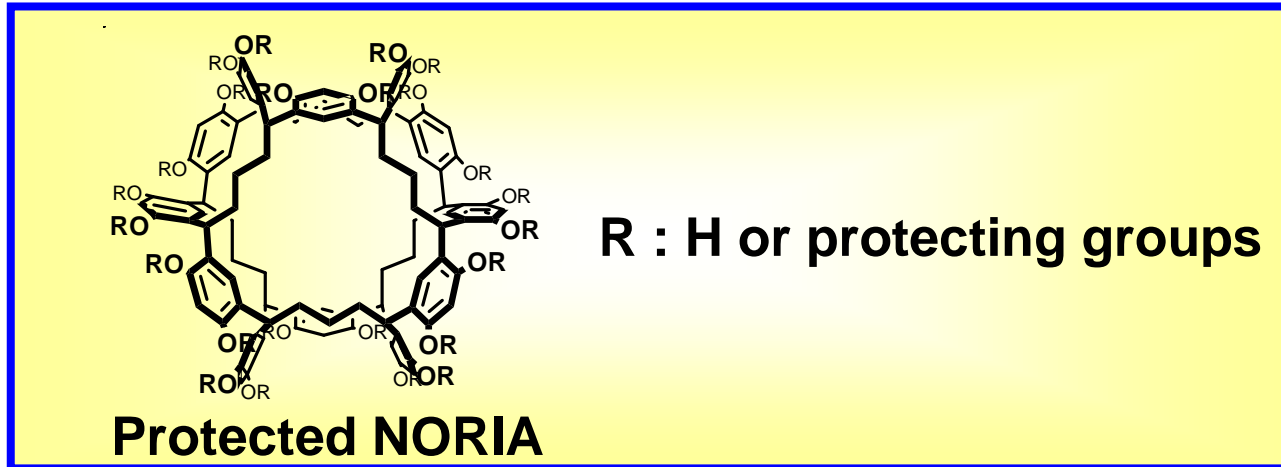
Table. Properties of NORIA

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

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



# Low molecular weight compound -Material to improve resolution-



**Pattern CD**

**30nmhp**

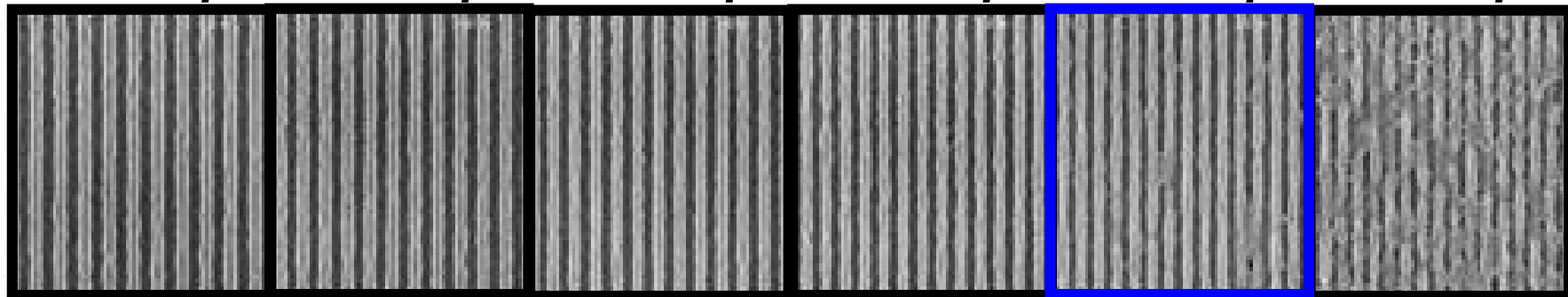
**28nmhp**

**26nmhp**

**24nmhp**

**22nmhp**

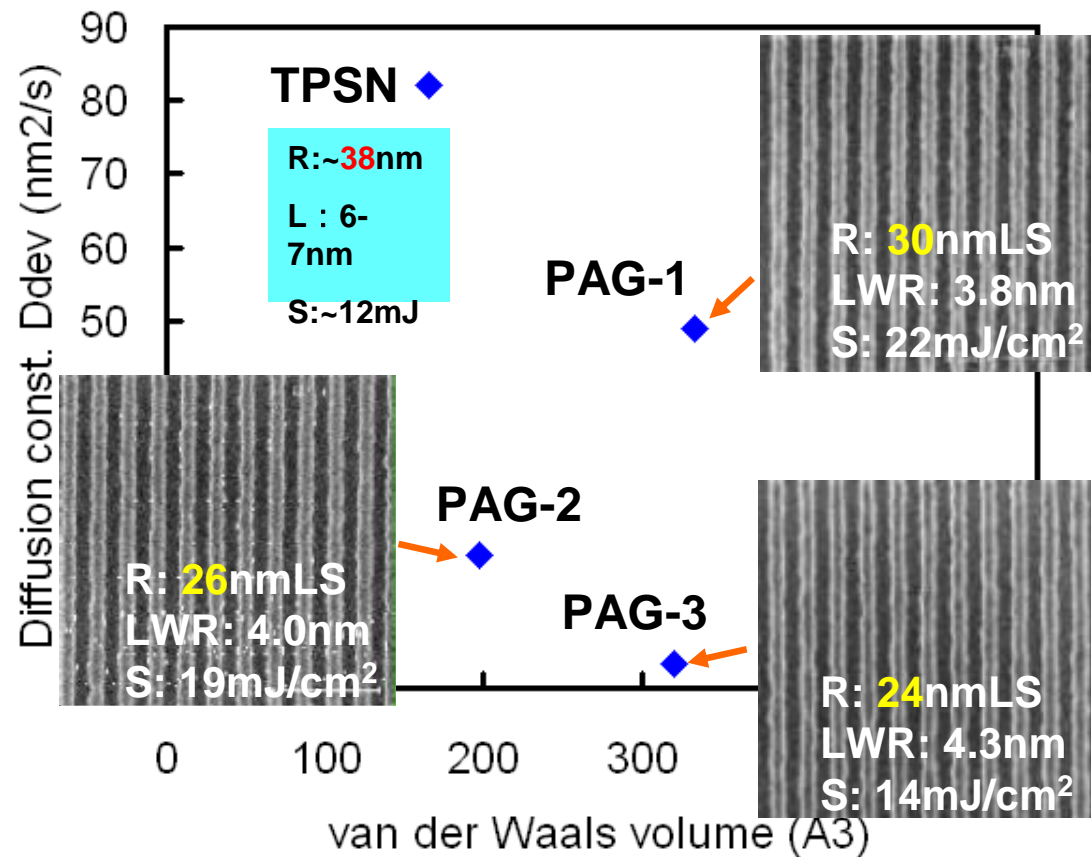
**20nmhp**



NA0.3, Quadrupole

- **Resist with NORIA resolved 22nmhp.**
- **Low molecular weight compound improved resolution.**

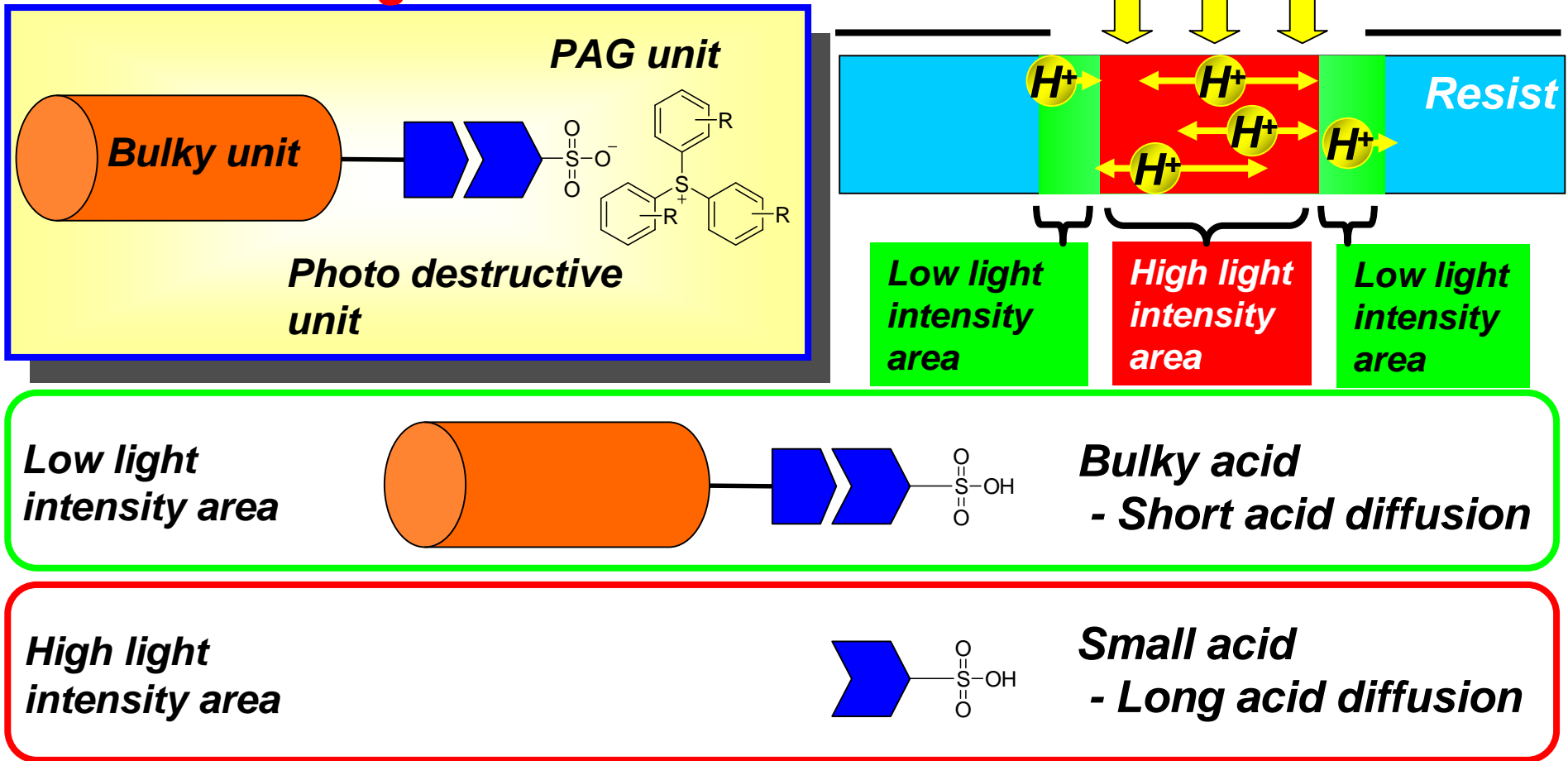
# RLS Improvement - New PAG System Development -



➤ **Short acid diffusion PAG improves RLS balance, especially for resolution.**

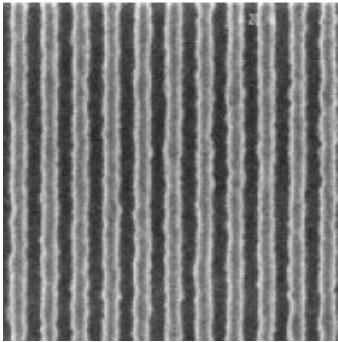
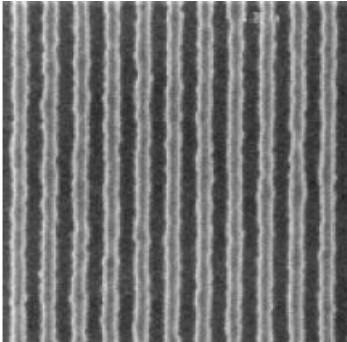
# Photo destructive anion PAG (PDA-PAG) -Materials to improve sensitivity-

## PDA-PAG design



➤ Resist evaluation using PDA-PAG was investigated.

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

	PDA-PAG	Conventional PAG (PAG-1)
Profile (30nm hp)		
Resolution	24nm hp	24nm hp
LWR (@30nm hp)	4.2nm	4.4nm
Sensitivity (@30nm hp)	16.7mJ/cm <sup>2</sup>	22.4mJ/cm <sup>2</sup>
Z-factor	4.0E-08	5.9E-08

\* NA0.3, Quadrupole

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

# Advanced Resist Performance

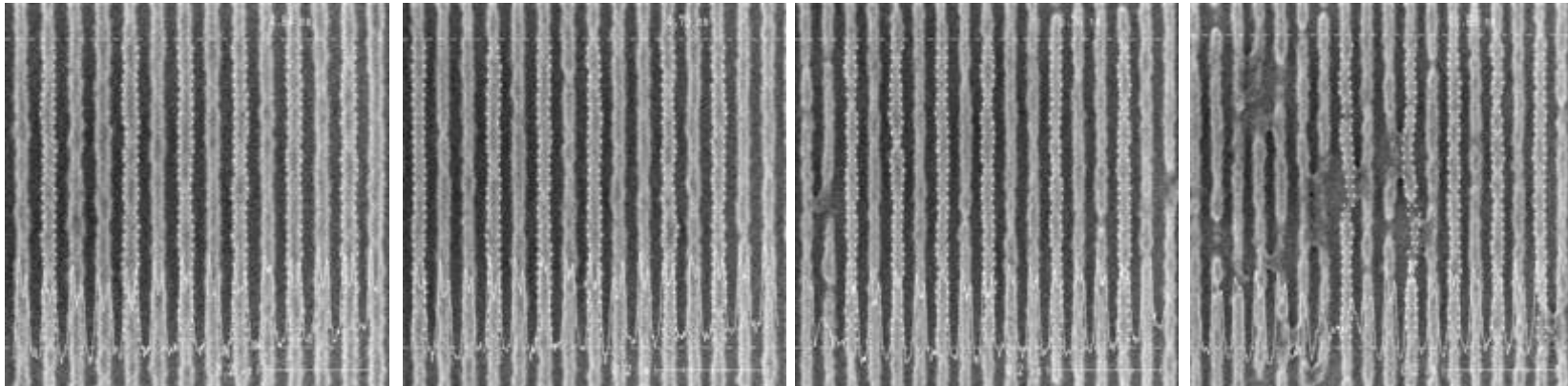
## Pattern CD

24nmhp

22nmhp

20nmhp

19nmhp



Resolution: 20nm hp

LWR (@20nm hp): 5.8nm

Sensitivity (@20nm hp): 15.7mJ/cm<sup>2</sup>

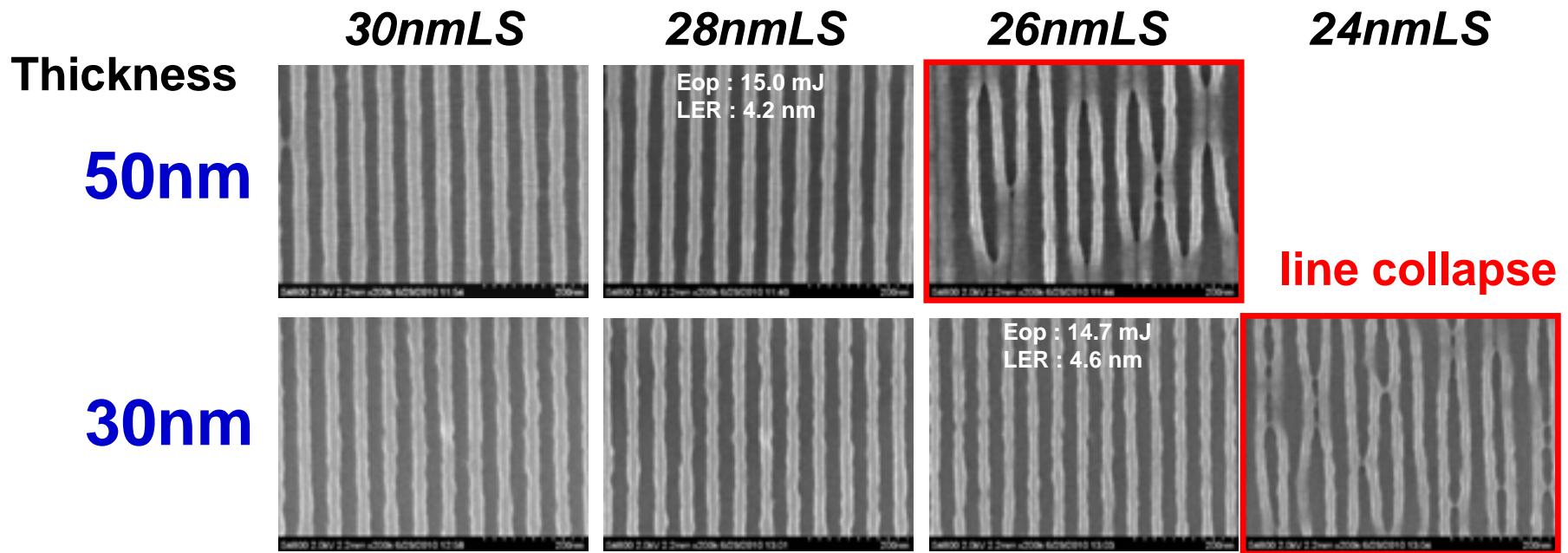
\* NA0.3, dipole

➤ *20nmhp resolution has been achieved with advanced EUV resist.*

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# Pattern Collapse Issue ~ 20nmLS

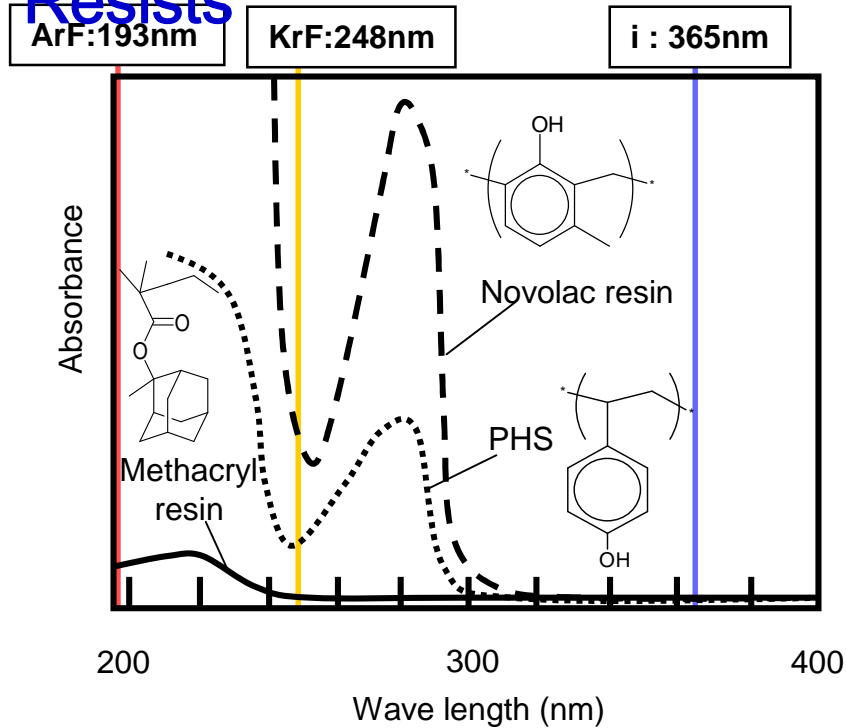


\* NA0.3, dipole

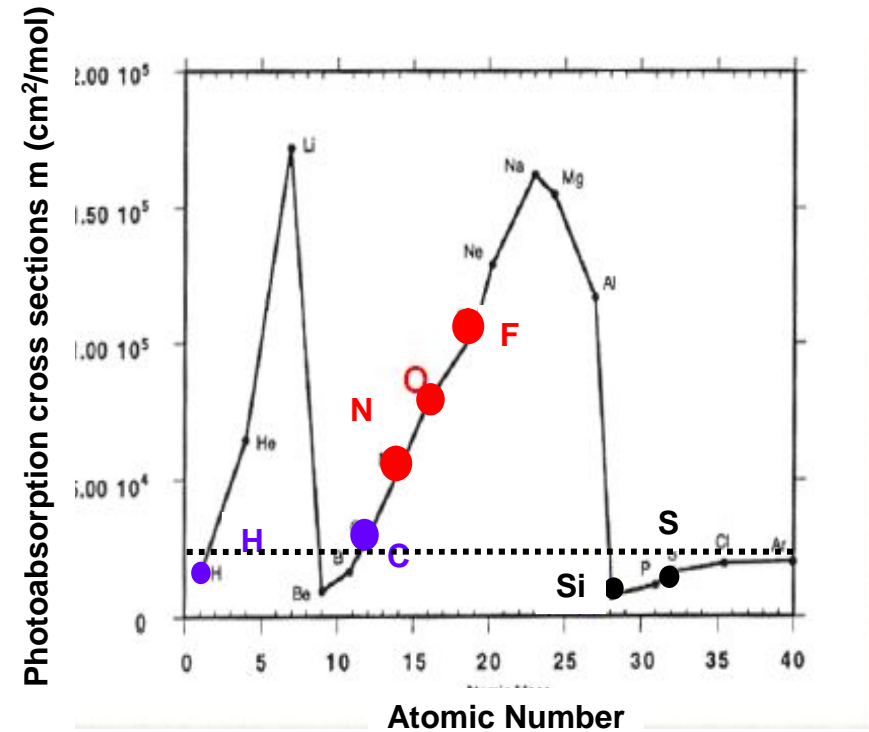
➤ *To achieve the resolution below 20nmhp, line collapse must be improved* → **Uniform acid generation and surface tension control will be the key to the solution**

# EUV Resist Absorbance

## Conventional Resists



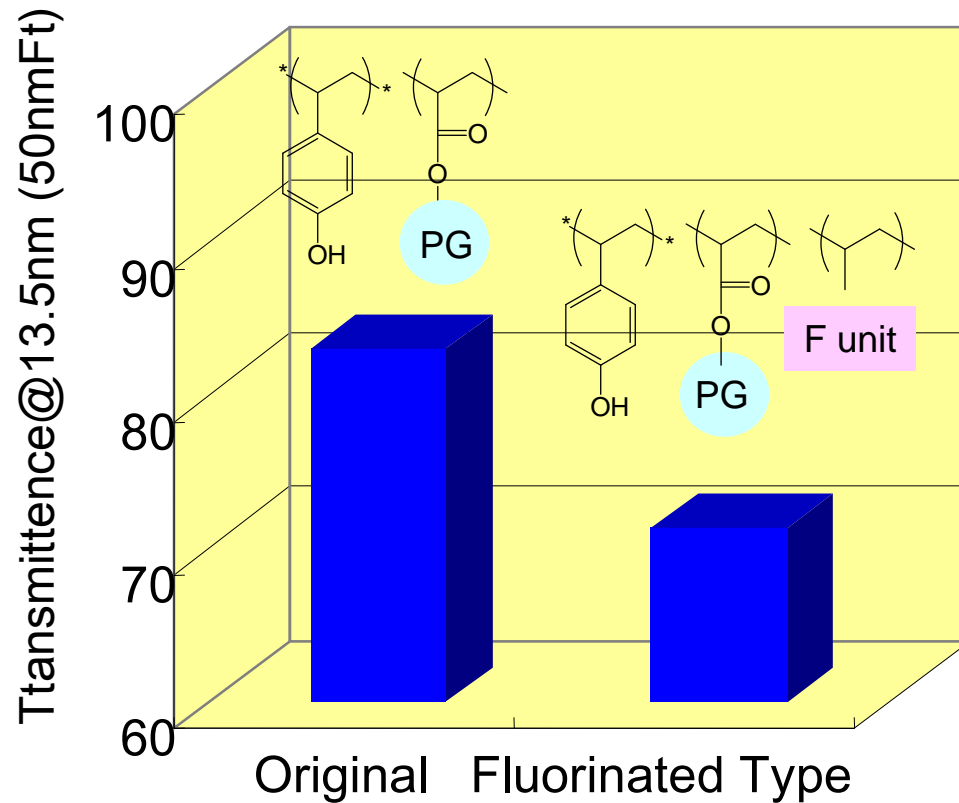
## EUV



- 1) Proc. SPIE. **3997**, P.588, 2000.
- 2) Atomic Data and Nuclear Data tables. **54(2)**, P.181, 1993.



# EUV Transmittance of Fluorinate Resist



\* Calculated values



# High Resolution Resist at 30nm Thickness

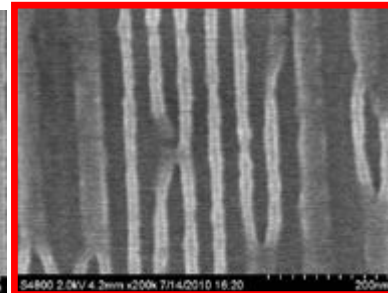
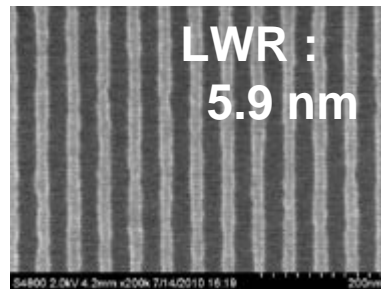
26nmLS

24nmLS

22nmLS

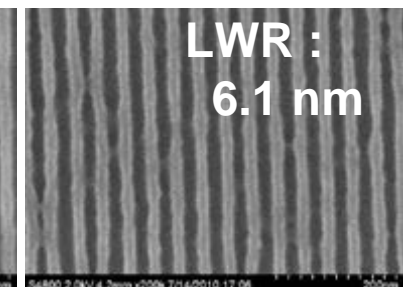
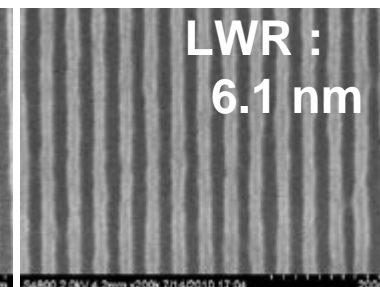
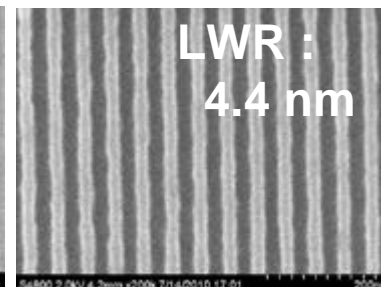
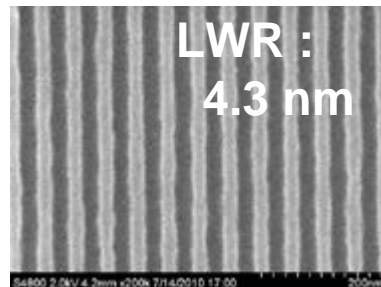
20nmLS

**Conventional Polymer System**



**line collapse**

**Fluorinated Polymer System**



\* NA0.3, dipole

➤ **Fluorinated polymer system improved the line collapse and resolution due to its high absorption and hydrophobicity.**

# Summary

- ***JSR's multiple approach for resist materials development contributes to EUV resist performance improvement.***
  - ***Low molecular weight compound : Resolution***
  - ***PDA-PAG : Sensitivity***
  - ***Fluorinated polymer: Profile and pattern collapse***
- ***Those new items improve resist performance and will push EUV technology for practical applications in the future.***

# Acknowledgement

- **Kanagawa University**
  - **Prof. Tadaomi Nishikubo**
  
- **Sematech**
  - **Warren Montgomery**
  - **Patrick Naulleau**