New approach for reducing the Out of Band effect and outgassing by applying top coat materials

Ryuji Onishi, Noriaki Fujitani,
Rikimaru Sakamoto, Bang-ching Ho

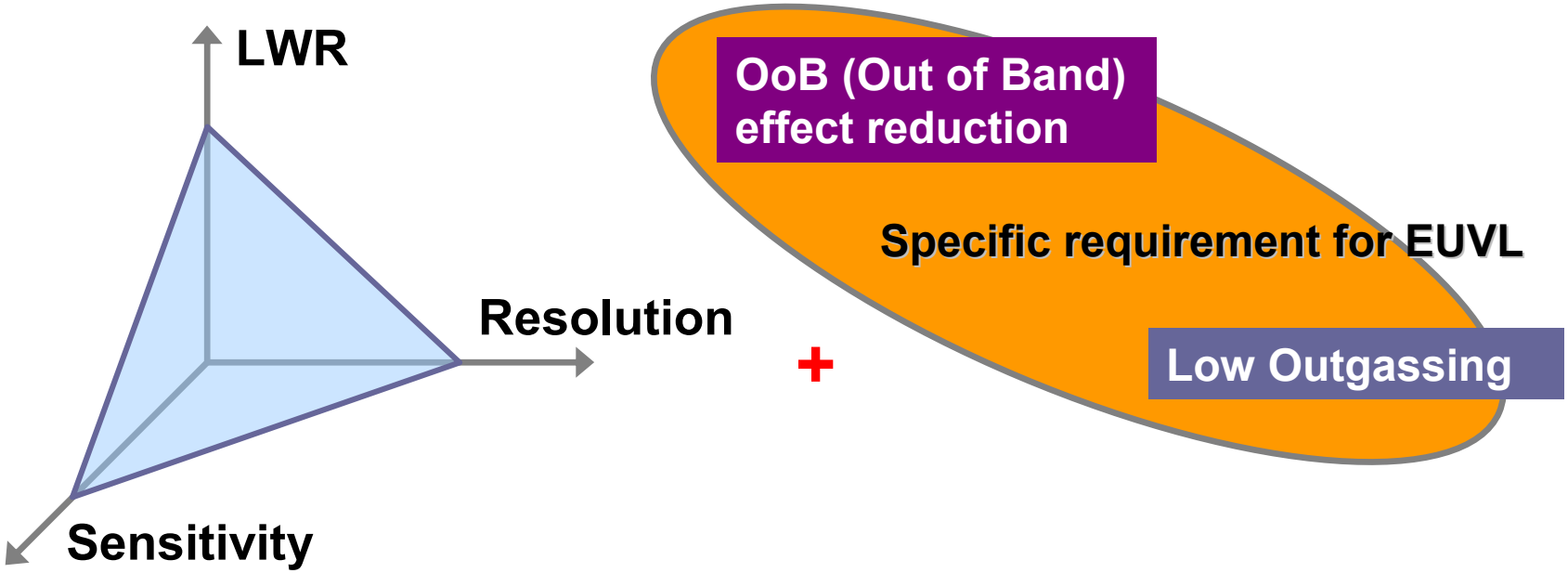
Semiconductor Materials Research Department,
Electronic Materials Research Laboratories,
Nissan Chemical Industries, LTD

Outline

- Introduction
- Material concept of top coat materials
- Evaluation result
- Conclusion

Introduction

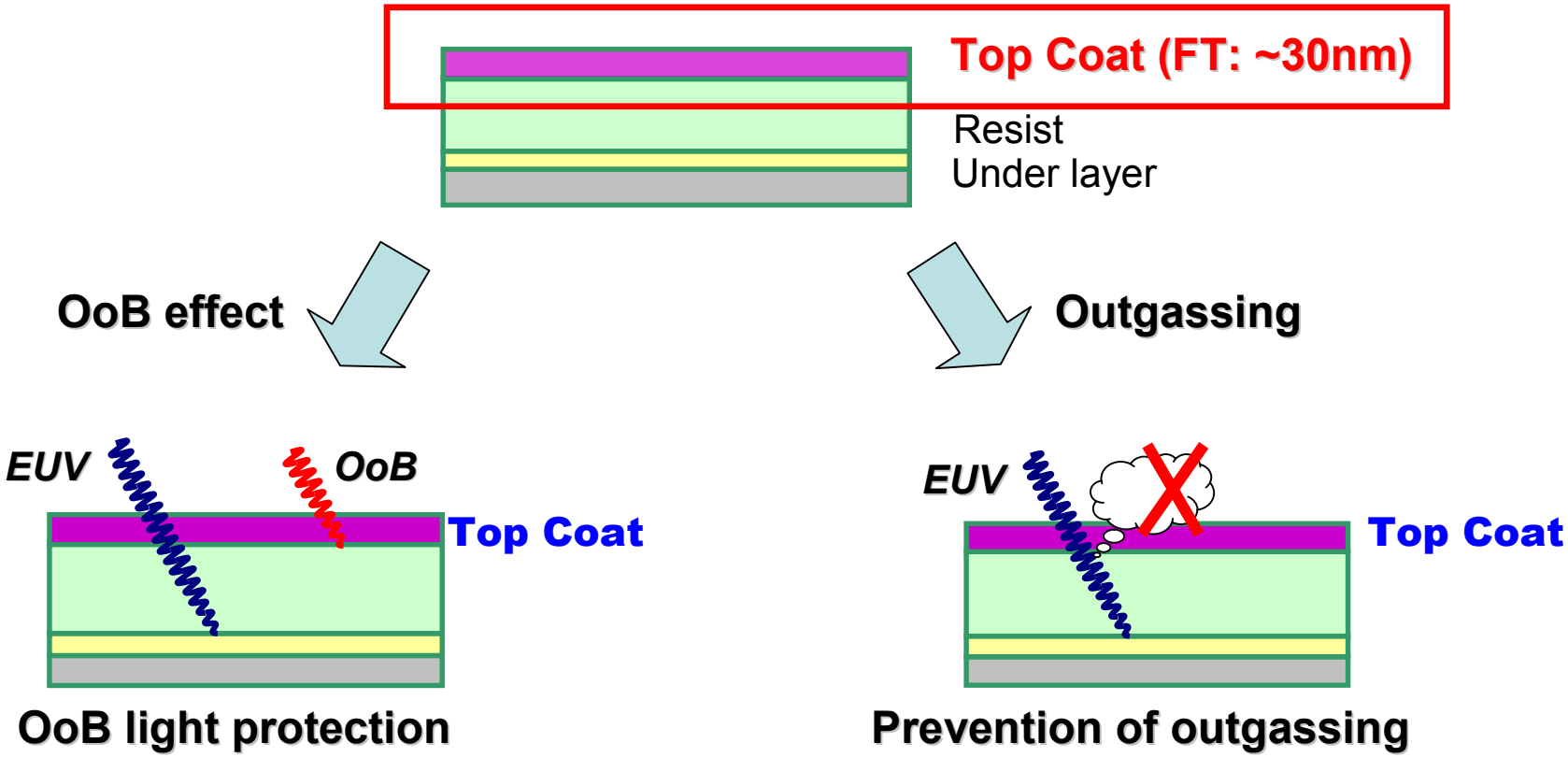
Requirement characteristic of EUV Lithography



Smaller RLS trade-off is required for resist development.

Additionally, OoB resistance and low outgassing is also required for EUV resist.

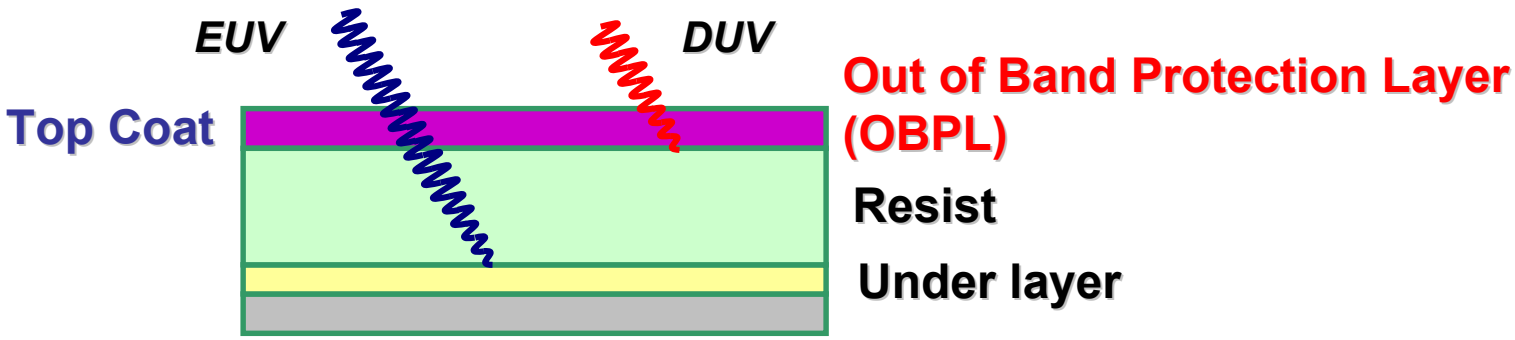
Proposal material



We propose top coat materials for EUV process.

Concept of Top Coat material

Target 1. Absorption of OoB light
2. Prevention of outgassing from resist



Characteristic of OBPL :

1. Low transmittance for OoB light
2. High transmittance for EUV light
3. Prevention of outgassing from resist

} Specific property for EUVL

4. No mixing with resist film
5. Removable by development and rinse process

} Common property with TARC and imm. TC

Material design

Sample	Alcohol type	Water type
Solvent	4-methyl-2-pentanol (MIBC)	Pure water (H_2O)
Target resist	Pure methacrylate type **(Inapplicable for resist including PHS structure)**	**All resist type**
Characteristic	OoB protection	
	Outgassing barrier	
	Good lithography performance	
Development situation	EUV exposure and outgassing test done	Evaluation start

Main topic

Evaluation item

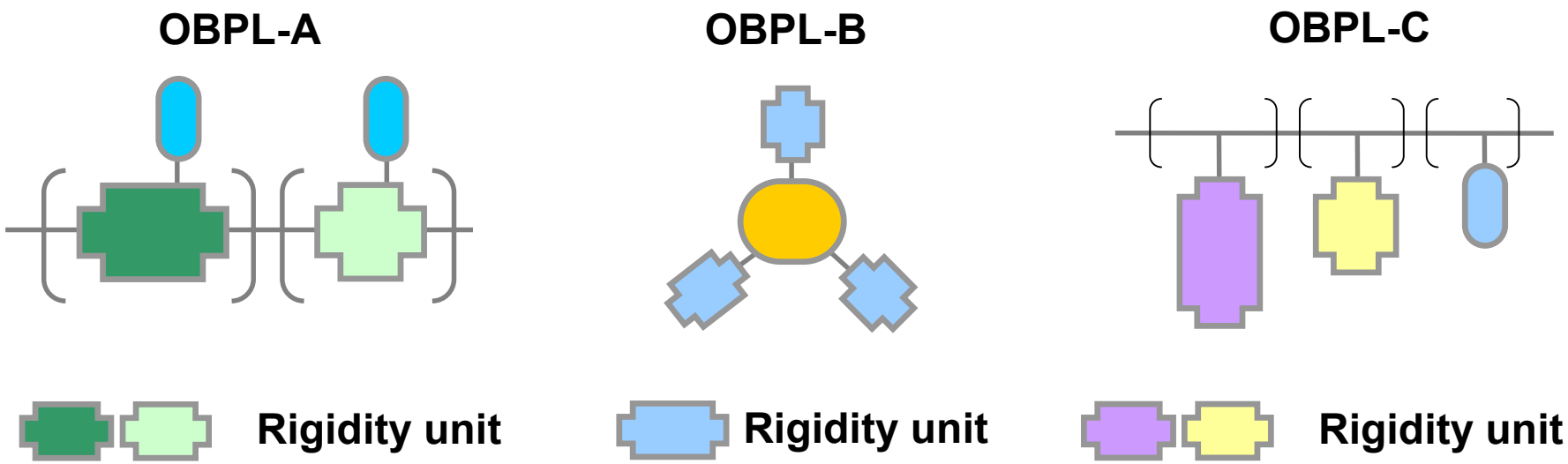
Evaluation OBPL sample: Alcohol type

Evaluation item

- **Optical property**
- **Outgassing**
- **EUV lithography performance**

Material design

Evaluation OBPL sample



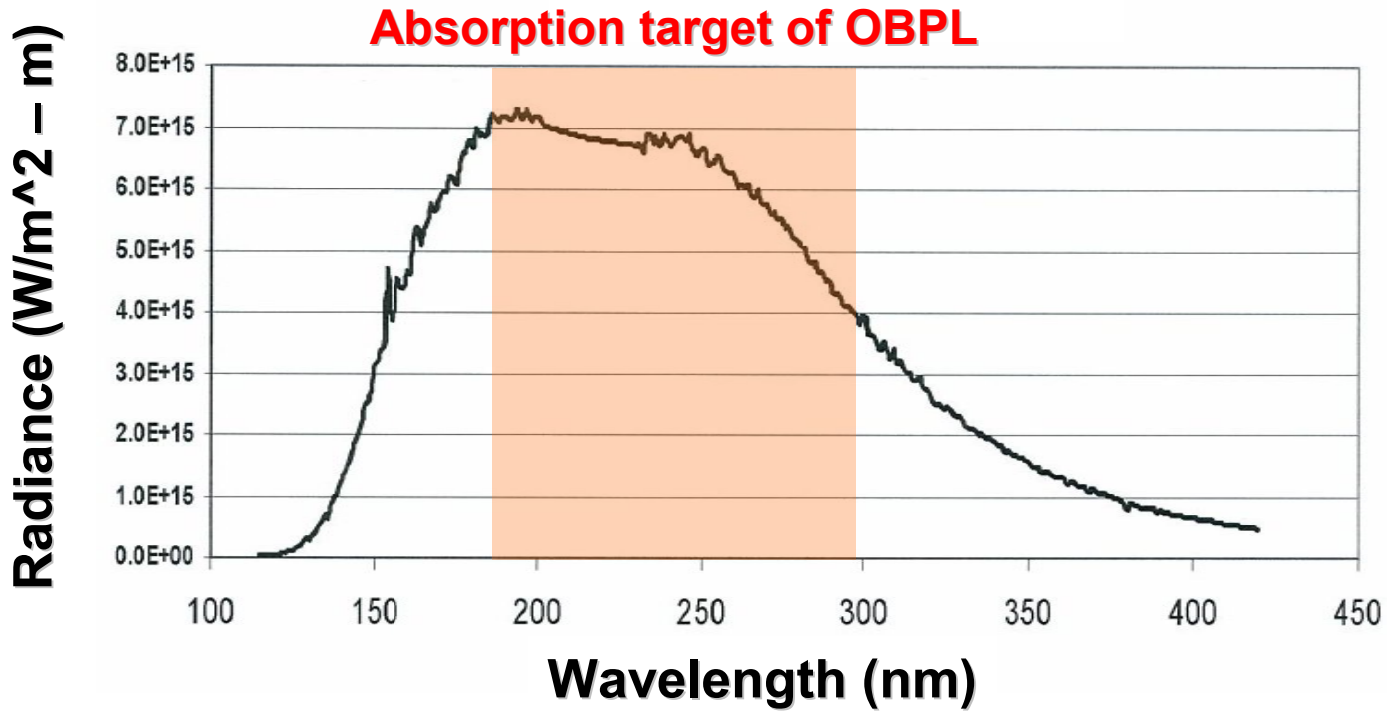
OBPL sample name		OBPL-A	OBPL-B	OBPL-C
Composition ratio	Rigidity unit	High	Middle	Low

Rigidity unit: concept unit for outgassing barrier

Out of Band light

Heidi Cao et. al.,
EUV symposium (2004)

OoB radiation at wafer plane

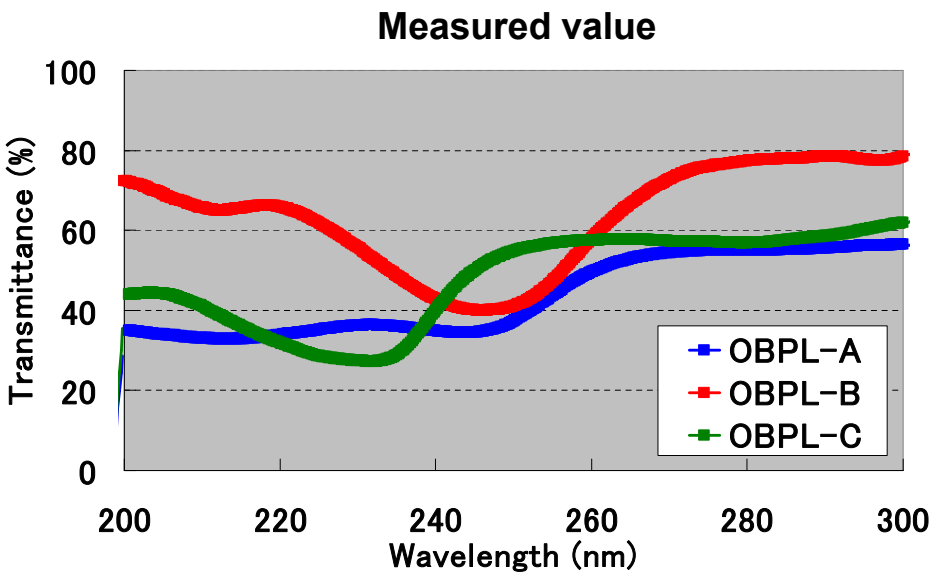


The peak top of OoB light is around 240nm.

Absorption target of OBPL is designed around 240nm

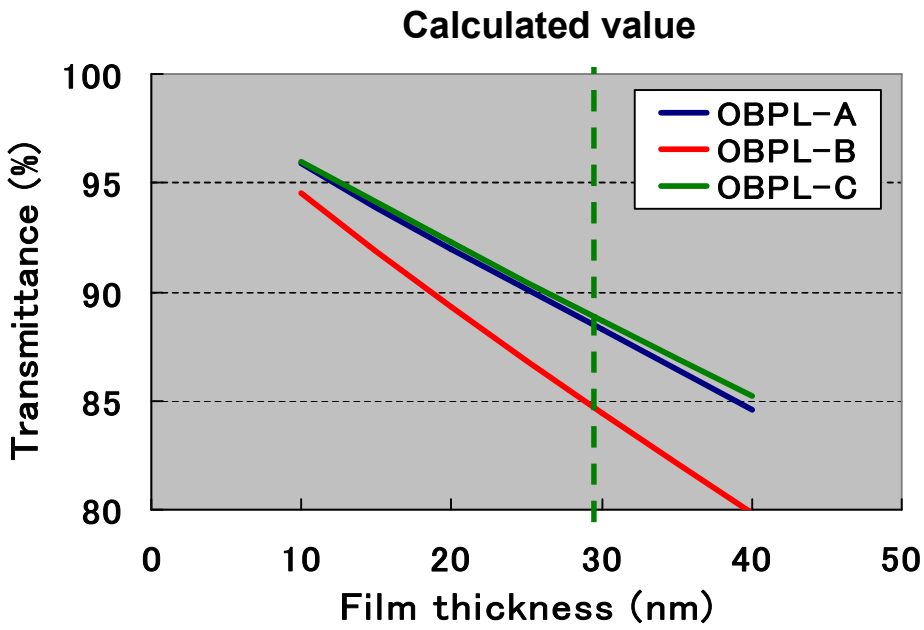
Optical parameter of OBPL materials

DUV transmittance(%) vs Wavelength (nm)



OBPL film thickness (FT): 30nm

EUV transmittance(%) vs Film thickness (nm)



OBPL showed low transmittance value for 200~300nm wavelength.

EUV transmittance is about 90% at 30nm film thickness.

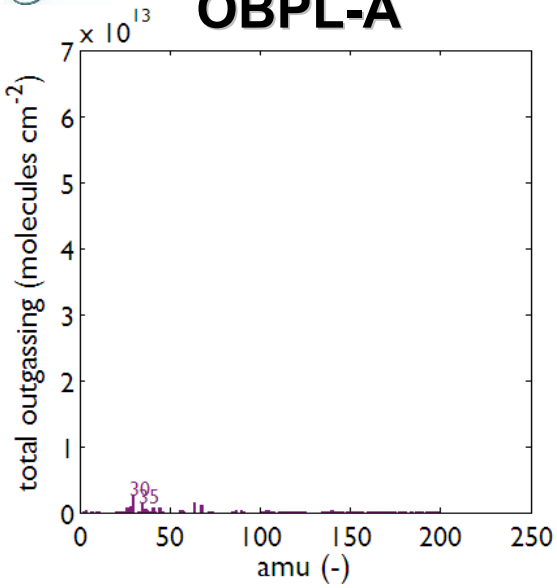
Outgassing from OBPL

Evaluation stack

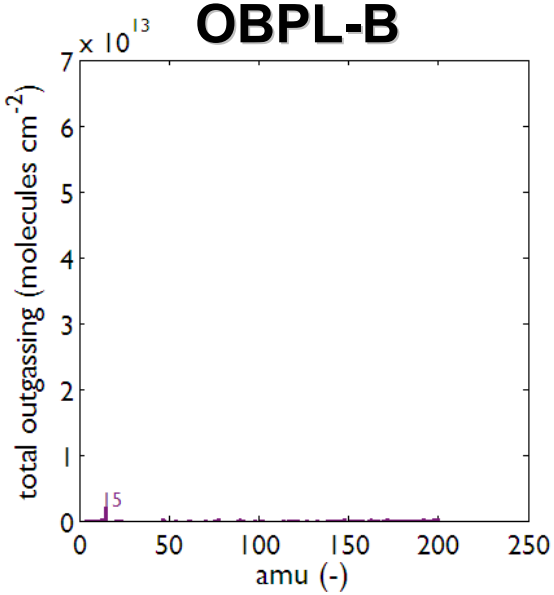
OBPL
Si Sub.

Evaluation tool: RGA

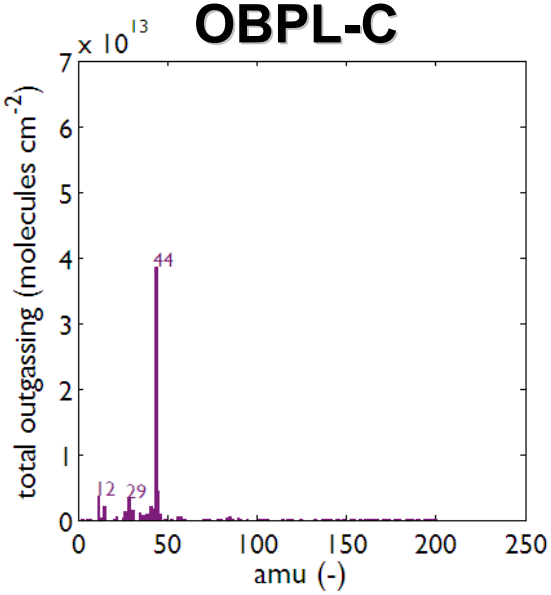
OBPL-A



OBPL-B



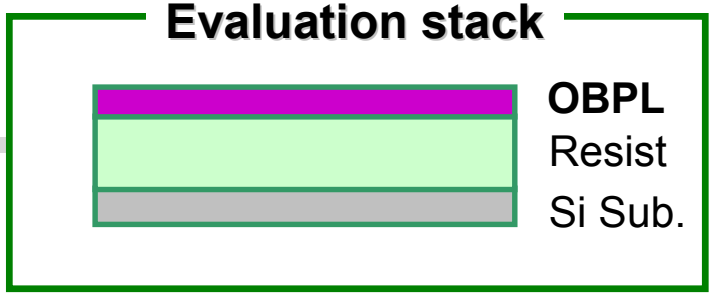
OBPL-C



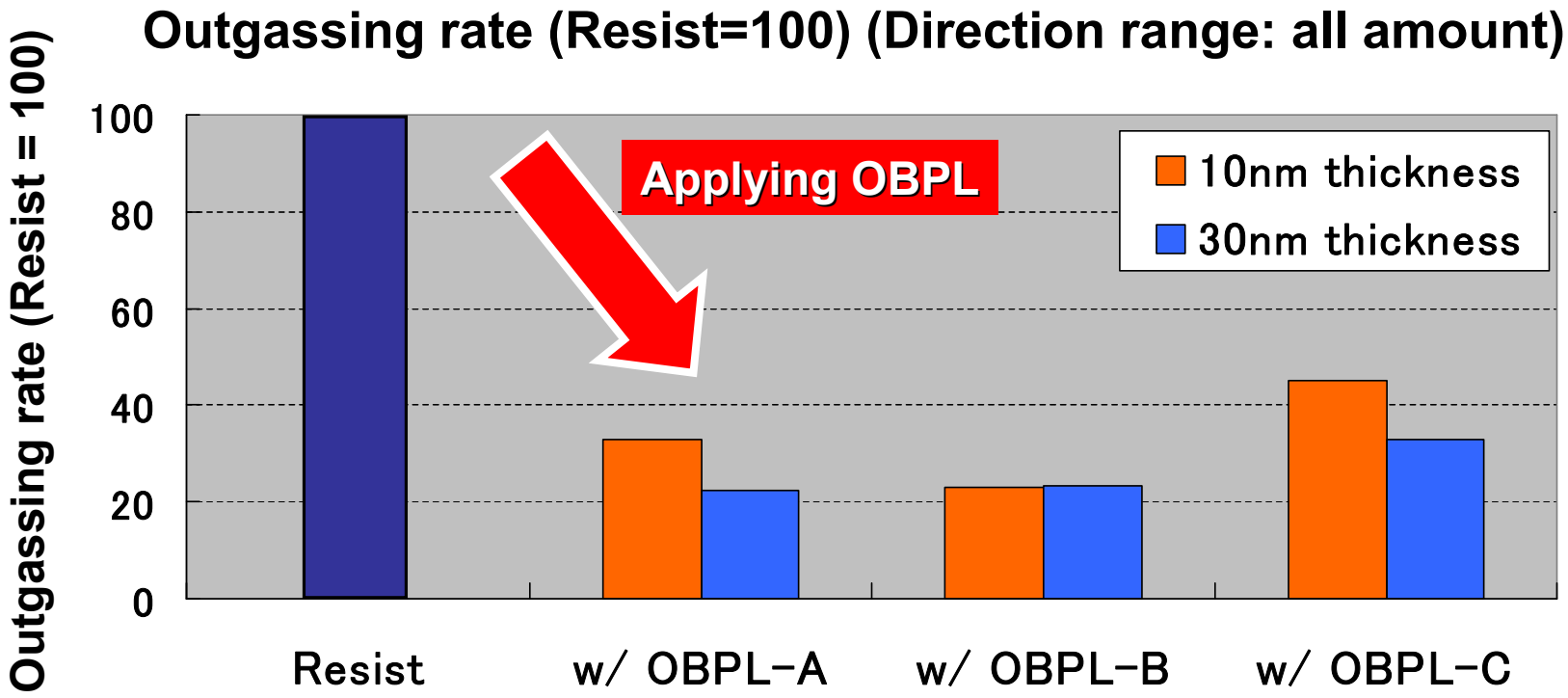
OBPL sample name		OBPL-A	OBPL-B	OBPL-C
Outgassing rate (45~200 amu)	FT: 10nm	1.61E+13	4.64E+12	3.26E+13
	FT: 30nm	1.78E+13	1.12E+13	7.18E+13
Target		< 5.00E+14		

Outgassing rate from OBPL film was shown value within limit in target.

Outgassing barrier property (Total amount)

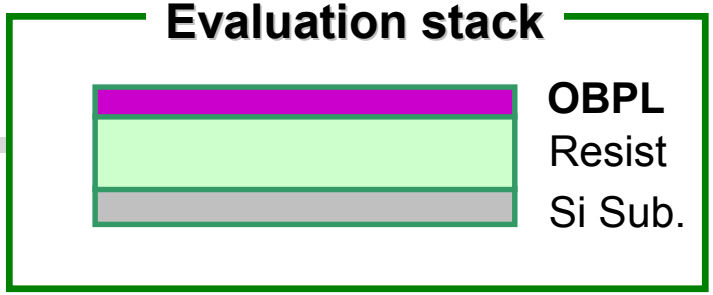


Evaluation tool: RGA



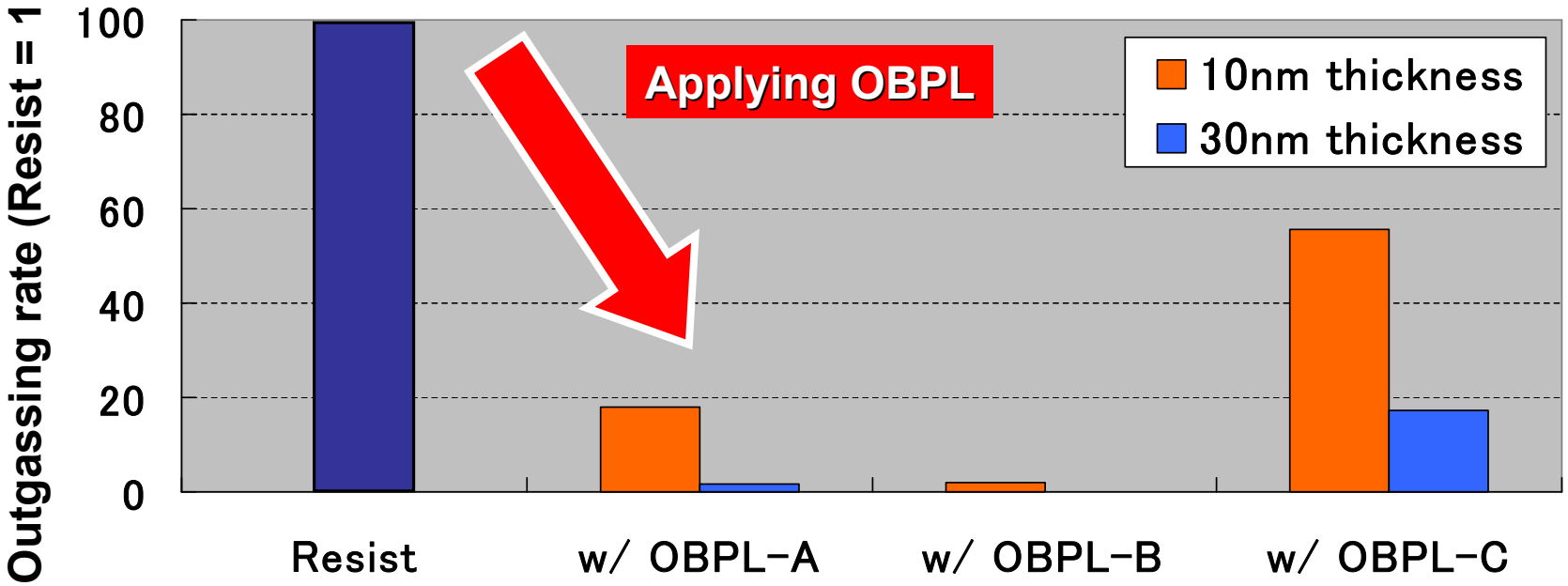
OBPL can reduce the outgassing from resist.

Outgassing barrier property (PAG component)



Evaluation tool: RGA

Outgassing rate (Resist=100)(Direction range: benzene (amu78))



OBPL showed barrier property for typical outgassing of resist.
At thin thickness, OBPL also showed barrier property.

Short summary

OBPL sample name		OBPL-A	OBPL-B	OBPL-C
Composition ratio	Rigidity unit	High	Middle	Low
Outgassing from OBPL		Within spec	Within spec	Within spec
Outgassing rate (OBPL FT: 30nm) (Resist=100) (all amount)		22.4	23.2	32.9
Outgassing rate (OBPL FT: 30nm) (Resist=100) (PAG component)		1.8 ☺	0.0 ☺	17.2 ☹

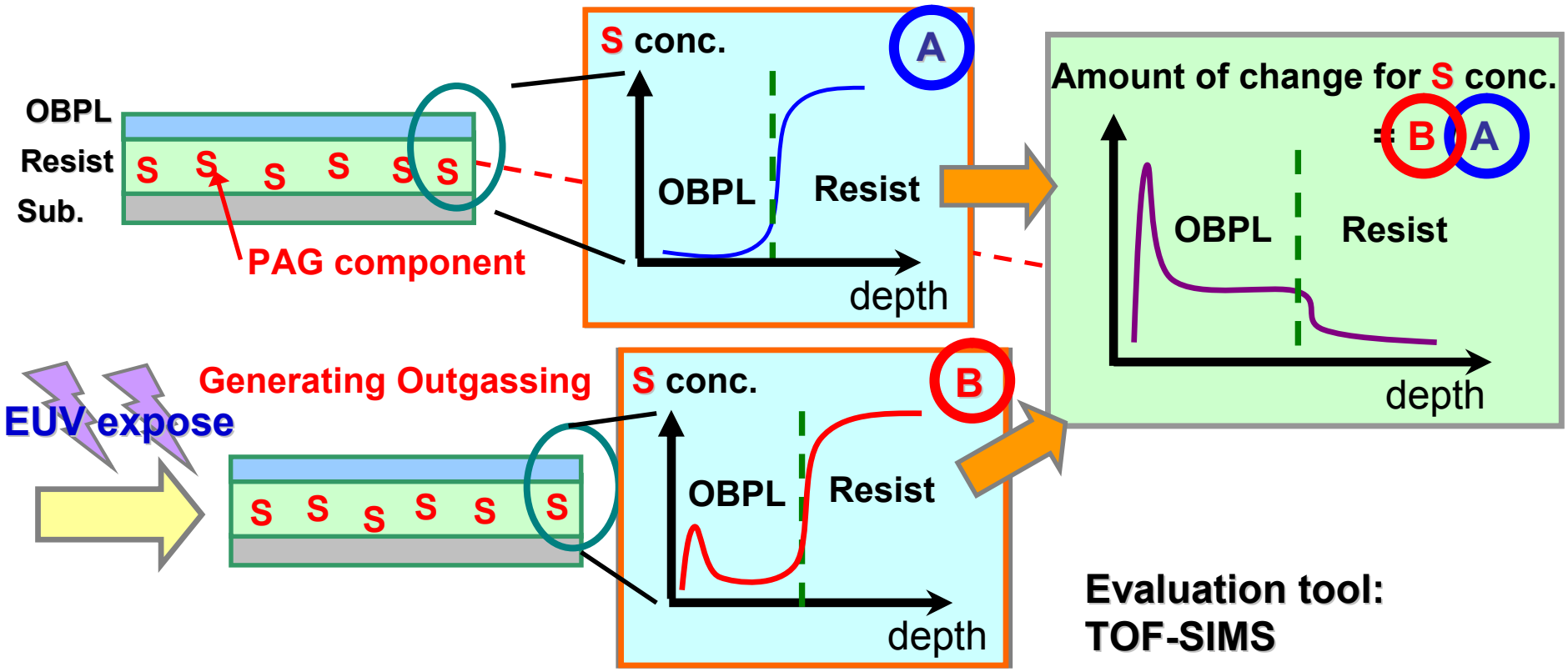
Evaluation tool: RGA

Evaluation sample from next page

Rigidity unit of OBPL is key factor for outgassing barrier property.
Barrier property is different by each OBPL structure.

Outgassing distribution analysis

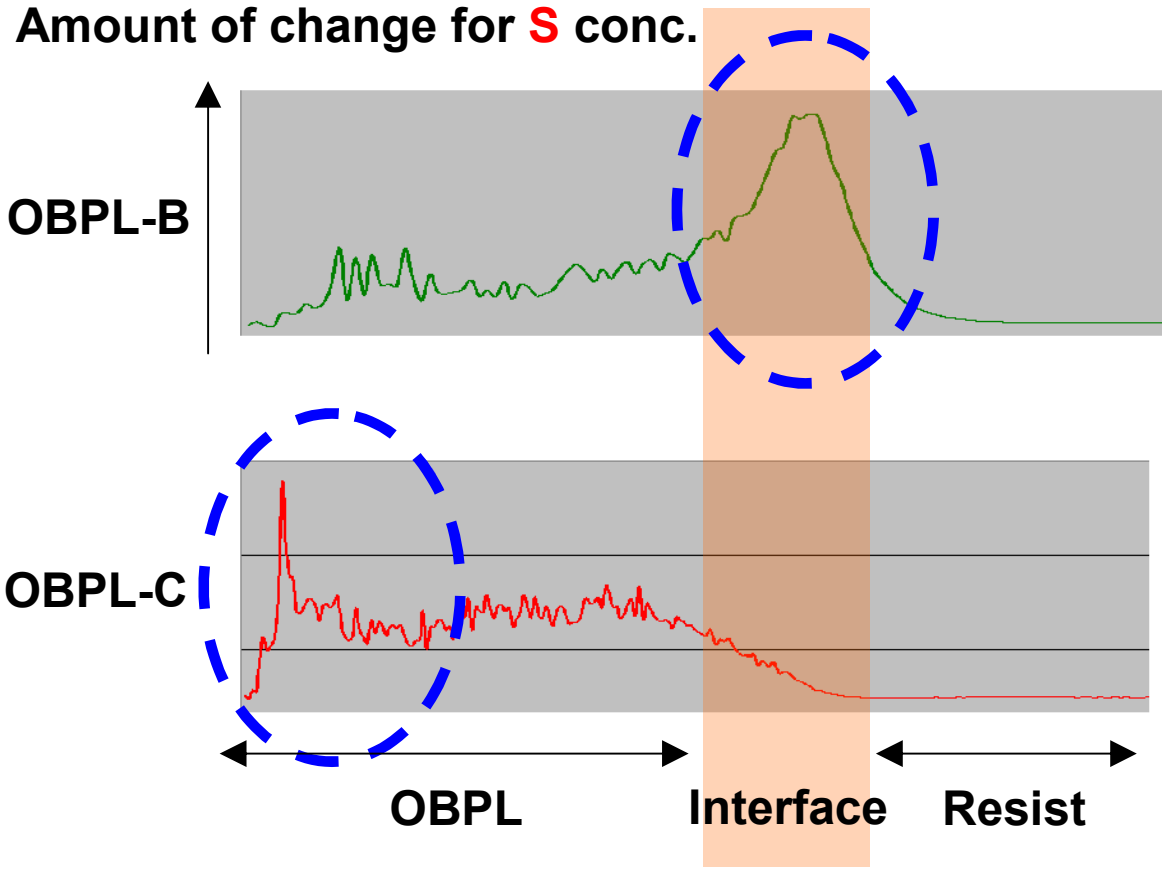
Where does outgassing distribute in OBPL film?



Evaluation tool:
TOF-SIMS

Variation of S conc. between before and after expose is investigated.

Outgassing distribution analysis



Outgassing barrier ratio: **High**

Distribution of S unit:
It localized to interface between OBPL and resist.

OBPL-B block outgassing to interface.

Outgassing barrier ratio: **Middle**

Distribution of S unit:
It localized to OBPL surface.

Outgassing is easy to move In OBPL-C film.

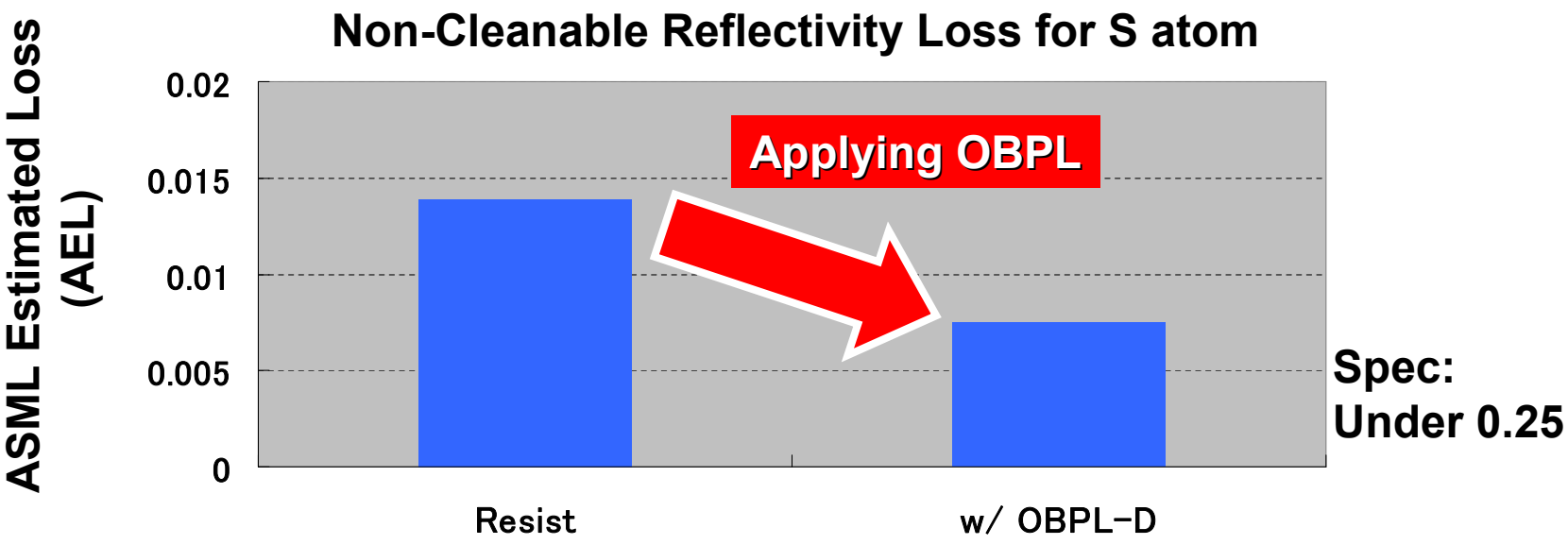
For OBPL showing low barrier property, outgassing is easy to move in OBPL film.

Outgassing test using witness plate

Tester / location: CNSE ROX

OBPL-D is similar to OBPL-A.

Evaluation sample	Resist	OBPL-D / resist
Cleanable contamination thickness	0.5nm	0.21nm
Maximum allowable value	3.0nm	



Outgassing barrier property of OBPL was also shown using witness plate.

EUV exposure test (26nmhp)

SEMATECH

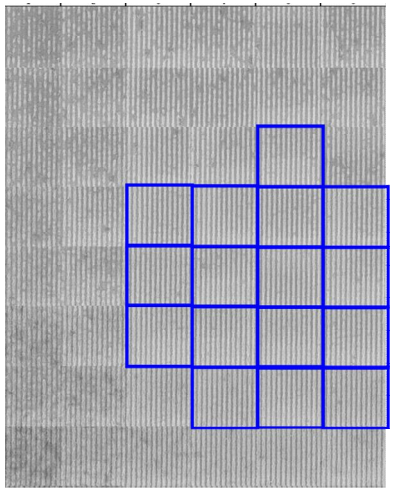
Pattern standing

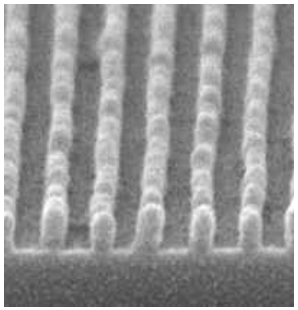
OBPL-E, F are similar to OBPL-A.

Dose

Focus

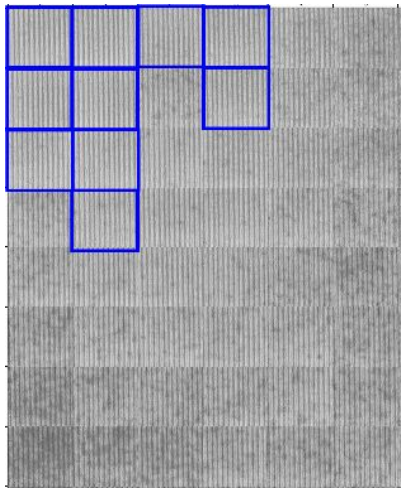
w/o OBPL

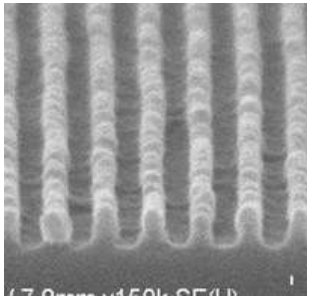




Eop:	13.2mJ
LWR:	5.5nm
DOF:	>120nm
MinCD:	22.7nm
EL:	9.1%

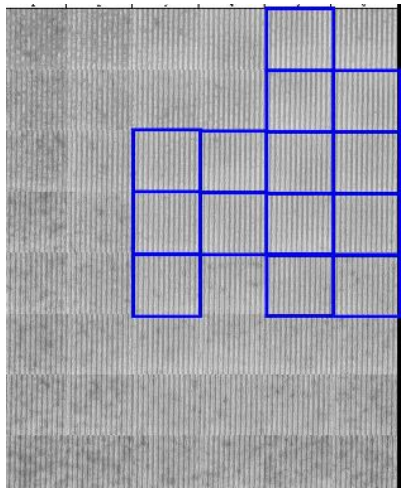
OBPL-E

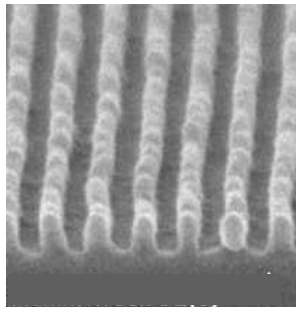




Eop:	15.0mJ
LWR:	5.6nm
DOF:	>120nm
MinCD:	<26.3nm
EL:	>6.0%

OBPL-F



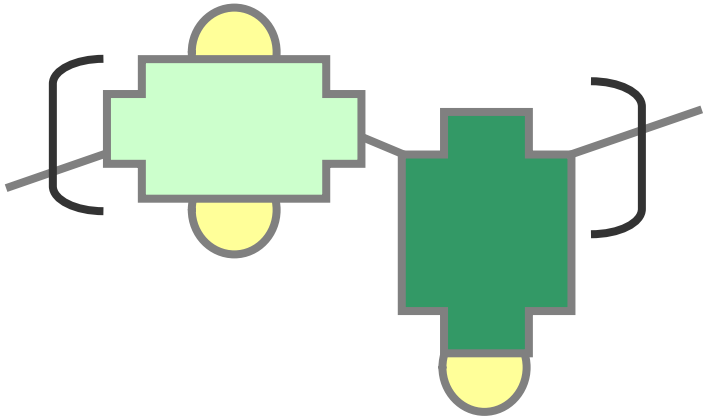


Eop:	14.4mJ
LWR:	6.9nm
DOF:	>120nm
MinCD:	<22.9nm
EL:	>8.3%

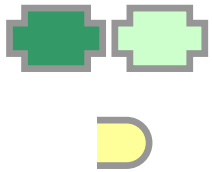
OBPL material showed good process margin and pattern profile.

Candidate sample (OBPL-E)

Sample name: NCX2055



Solvent: MIBC (Alcohol type)

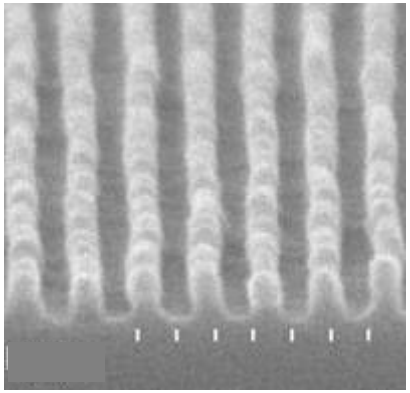


Rigid unit

Polar unit

Material property		Result
Transmittance (FT: 30nm)	240nm	31%
	13.5nm	88%
Outgassing (witness plate)	Only OBPL film	Within target
	OBPL / resist	Showed outgassing barrier

EUV litho performance



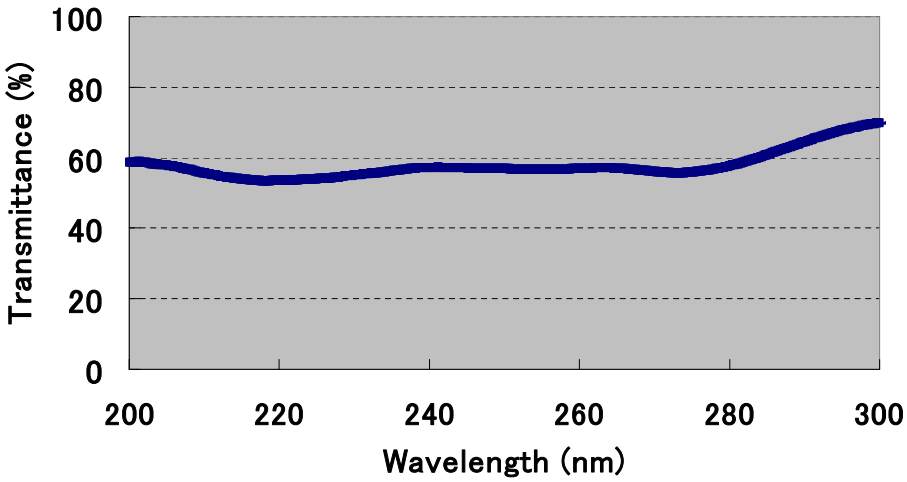
24nmhp

NCX2055 sample showed good performance for several property.

Water type OBPL

Solvent: Pure water
Applicable resist: All resist type

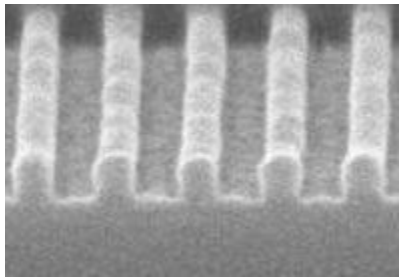
Optical property



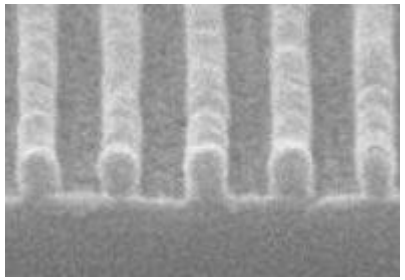
OBPL thickness: 30nm

Result of EB patterning

w/o OBPL



Applying OBPL



Target CD: 30nm hp

Resist: FEVS-P1507D (Fujifilm)

Water type also showed good performance as OBPL.

Conclusion

1. We focused on development of the resist top coat material for EUV process as OBPL (Out of Band Protection Layer).

2. OBPL material was designed to have low transmittance for OoB light and high transmittance for EUV light.

3. Outgassing amount of OBPL is within the target level. OBPL material can reduce outgassing from resist.

4. Result of EUV exposure, OBPL material showed good process margin and good pattern profile.

Thank you for your kind attention !!