Development of Under Layer material for EUV Lithography

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4. Study of acid generation efficiency at PR/UL interface.
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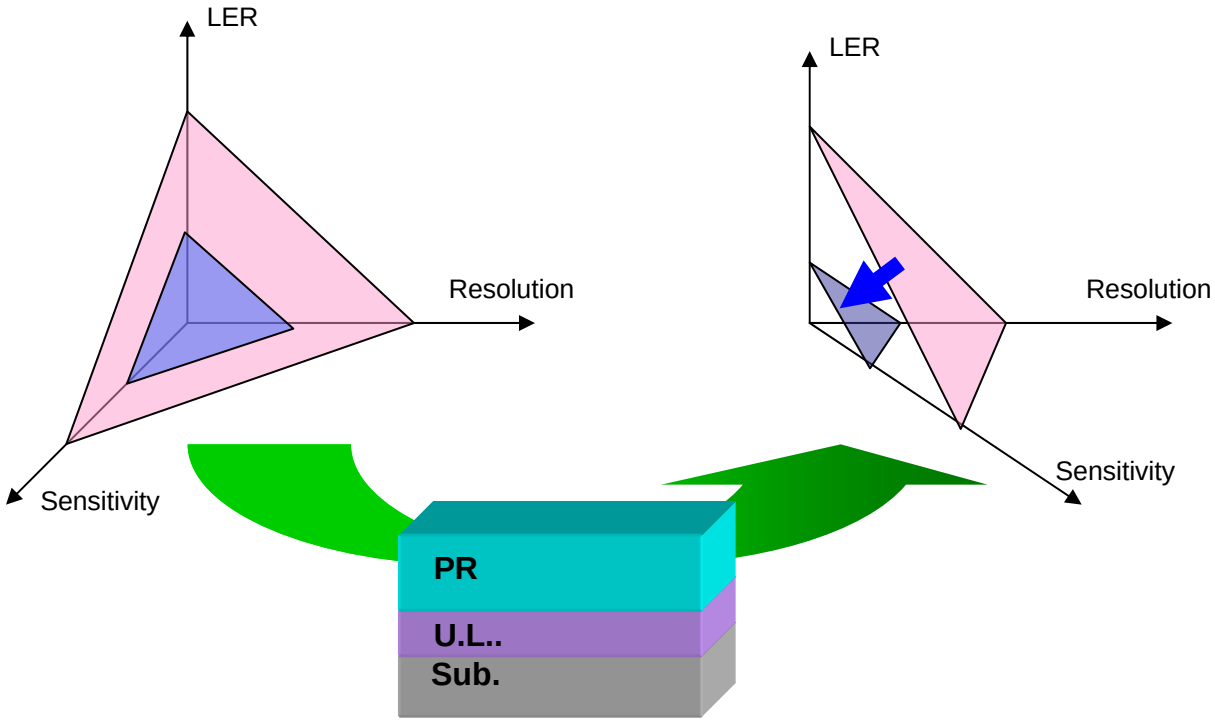
Nissan Chemical Industries, LTD.

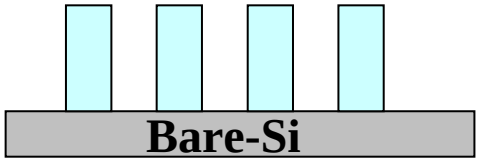
RLS trade off



Adding Functional-underlayer into between PR and substrate, Underlayer is targeting make RLS trade-off smaller by supporting underlayer effect.

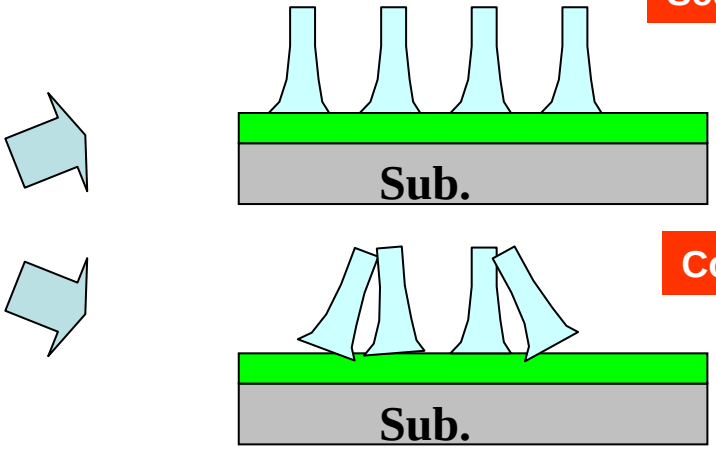
EUV UL material

PR development



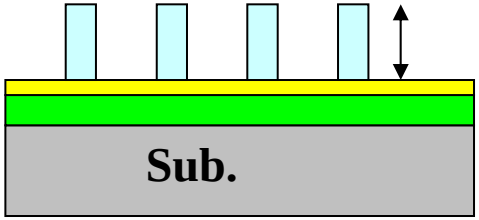
Si-Sub./HMDS is used as STD substrate.

Device Manufacturing



HM is used for actual process. Footing or Scumming Pattern shape or collapse issue can be concerned.

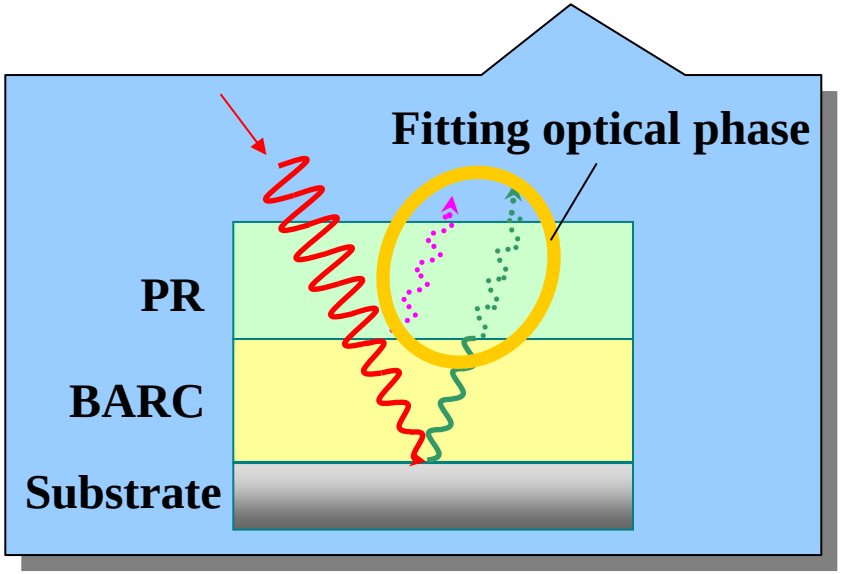
Appling UL material



UL can cancel the substrate effect.
Stable substrate condition is provided
By using UL material on various substrate.

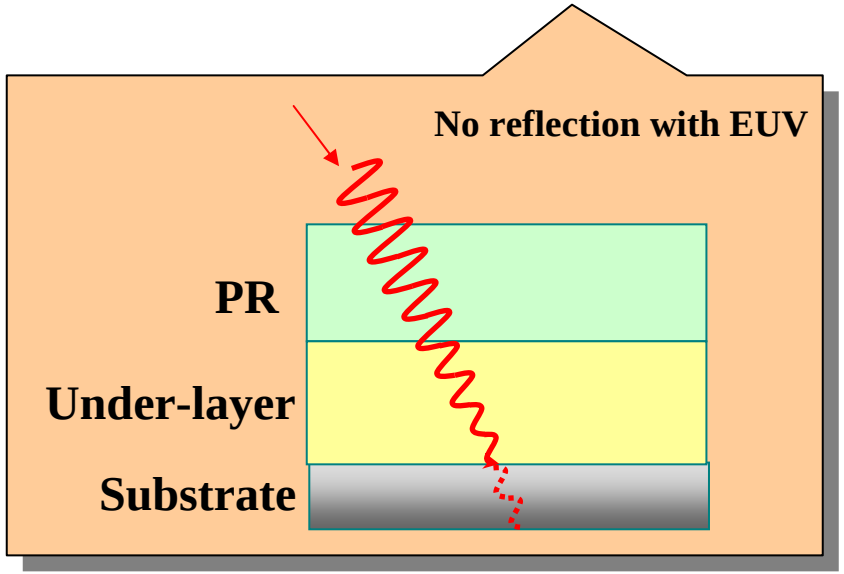
Opt. Lithography and EUV Lithography

Optical Lithography
(with g-line, i-line, KrF, ArF)



Reflectivity control is the key factor. BARC material is necessary for Optical Lithography.

EUV Lithography
(with 13.5nm)



No reflectivity control is necessary for EUV, Because EUV light is absorbed or path the layers. However, UL is used as adhesion and LWR reduction purpose.

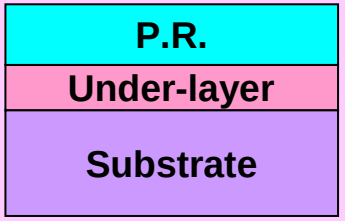
2. Requirement for EUV UL material

EUV
Challenging and Solution by x-layer

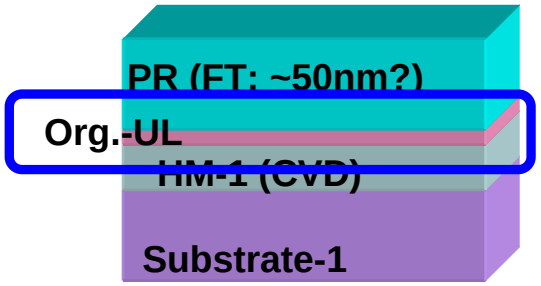
Requirements for EUV Under-layer

- High adhesion with PR
- Block the contamination from substrate (Barrier film)
- Good performance with thin film (~20nm)
- Good etch performance with fast etch rate or thin FTK.
- **No out gas**
- ***Photo speed, resolution enhancement***
- ***Reduce LWR, LER***

Stack structure;

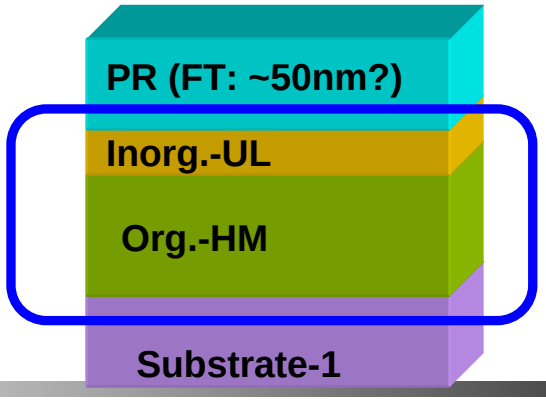


<HM+UL>



UL (FT: ~20nm)

<Tri-layer>



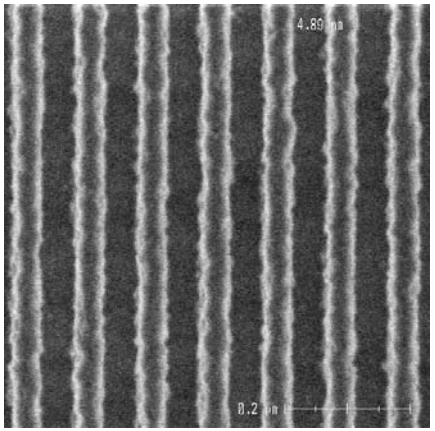
3. Investigation of LWR reduction

EUV

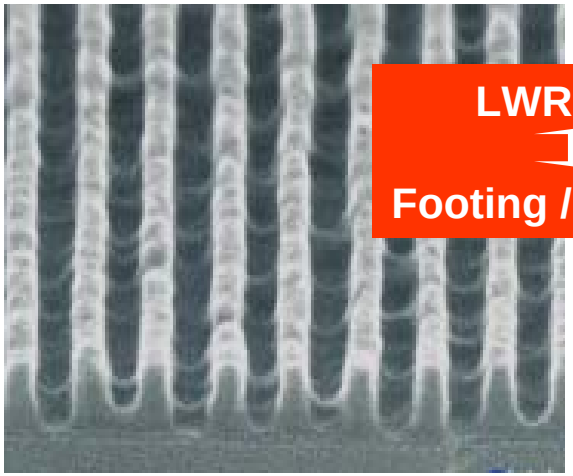
Challenging and Solution by x-layer

Material Concept for profile control

Top down



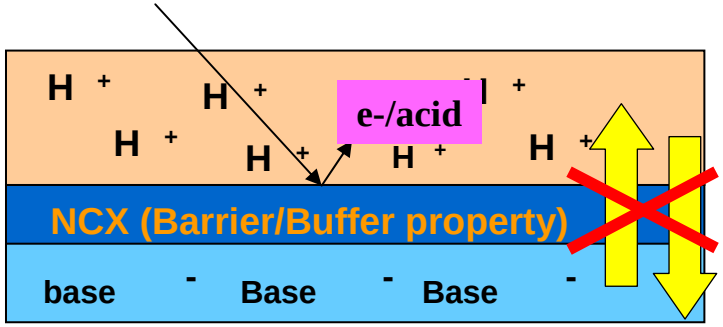
X section



LWR / LER

Footing / Scumming

Material concept



Concept-1

High film density (Physically barrier)

Acidity control

→ Common with Optical Lithography

Concept-2

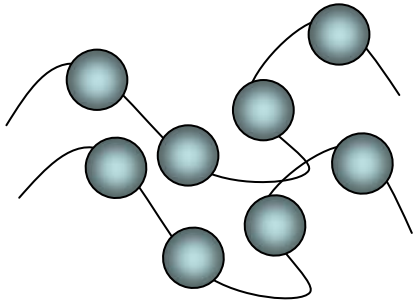
Enhancement of Acid generation efficiency

At interface between UL and PR.

→ Special for EUV

High Density UL material

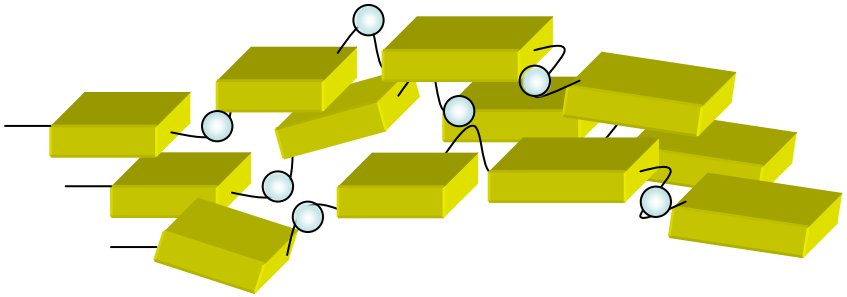
STD polymer for ARC



Chromophore, adhesion unit

Resin have some flexible structure
And/or including functional unit for PR/BARC
Adhesion.

Newly designed polymer for EUV



Functional unit (Adhesion, Crosslink)
Rigid and Bulky unit

Resin have rigid and bulky unit to
Make film more dense and rigid for
controlling acid/amine diffusion between
PR and U.L.

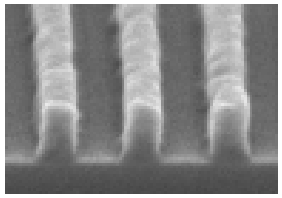
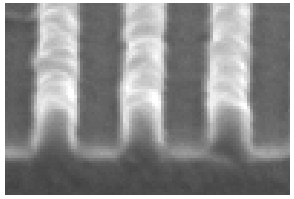
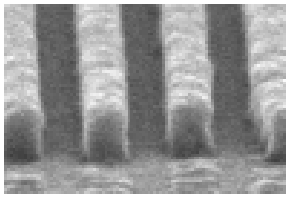
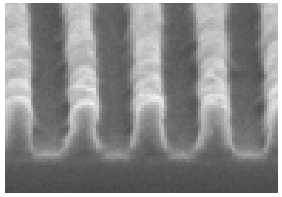
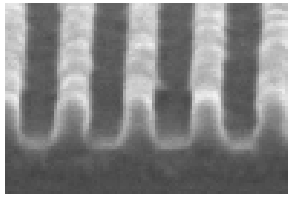
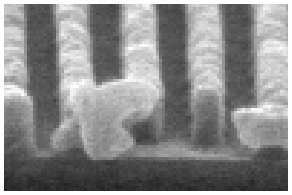
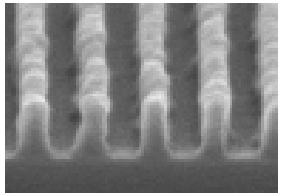
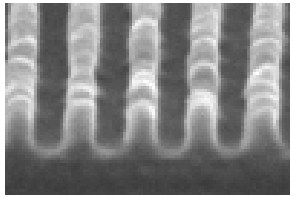
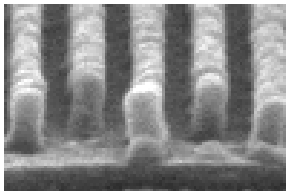
	n@633nm	density(g/cm3)
Acrylate(ref)	1.50	1.25
New system	**1.60**	**1.42**

Density was measured by X-ray refection method.

High Density UL material

EUV
Challenging and Solution by x-layer

SFET (Small Field Exposure Tool) : NA0.30, σ 0.7/0.3

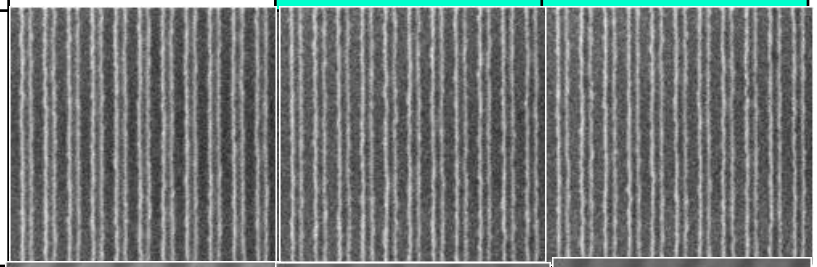
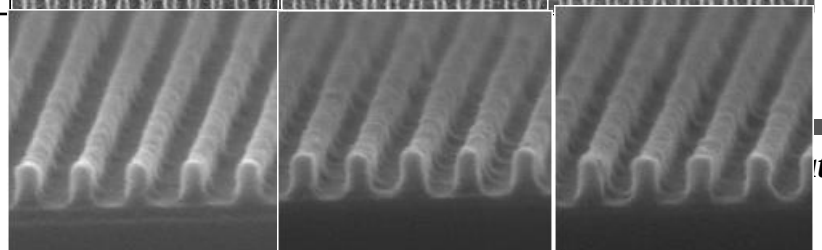
	Si-Sub./HMDS	Acrylate	***High-density***
HP 45			
HP 35			
HP 32			
	Taper/Footing profile	**Taper/Footing profile**	***Vertical profile***

SPIE 2009, 7273-113, Selete, D. Kawamura, et al.

High Density UL material

EUV
Challenging and Solution by x-layer

imec

		Ref.	High density UL-A	High density UL-B
30L60P @ LLF	Dose-to-size	14.0mJ/cm2	*14.7mJ/cm2	*15.2mJ/cm2
	LWR	3.7nm	3.7nm	3.7nm
	Max EL	20.4%	**26.1%**	**26.7%**
	Max DOF	160nm	160nm	160nm
30L60P @ 50DF	Dose-to-size	14.7mJ/cm2	*14.7mJ/cm2	*14.7mJ/cm2
	Max EL	12.9%	12.9%	**13.5%**
	Max DOF	80nm	**120nm**	**120nm**
30L180P @ LLF	Dose-to-size	13.4 mJ/cm2	*13.8 mJ/cm2	*13.7 mJ/cm2
	Max EL	20.7%	**21.5%**	**21.3%**
	Max DOF	160nm	160nm	150nm
30L300P @ LLF	Dose-to-size	13.8 mJ/cm2	*14.2 mJ/cm2	*14.1 mJ/cm2
	Max EL	24.3%	23.0%	24.2%
	Max DOF	140nm	**200nm**	**160nm**
Ultimate Resolution		28nm HP	**27nm HP**	**27nm HP**
Most Standing CD (Pattern Collapse)		29.3nm	**27.4nm**	**27.3nm**
Top Profile 30L60P @ LLF				
X-section Profile 30L60P @ LLF				

ADT
NA=0.25, 0.5 σ
30nm HP

LER on Si >4.5nm

Better performance

tories.

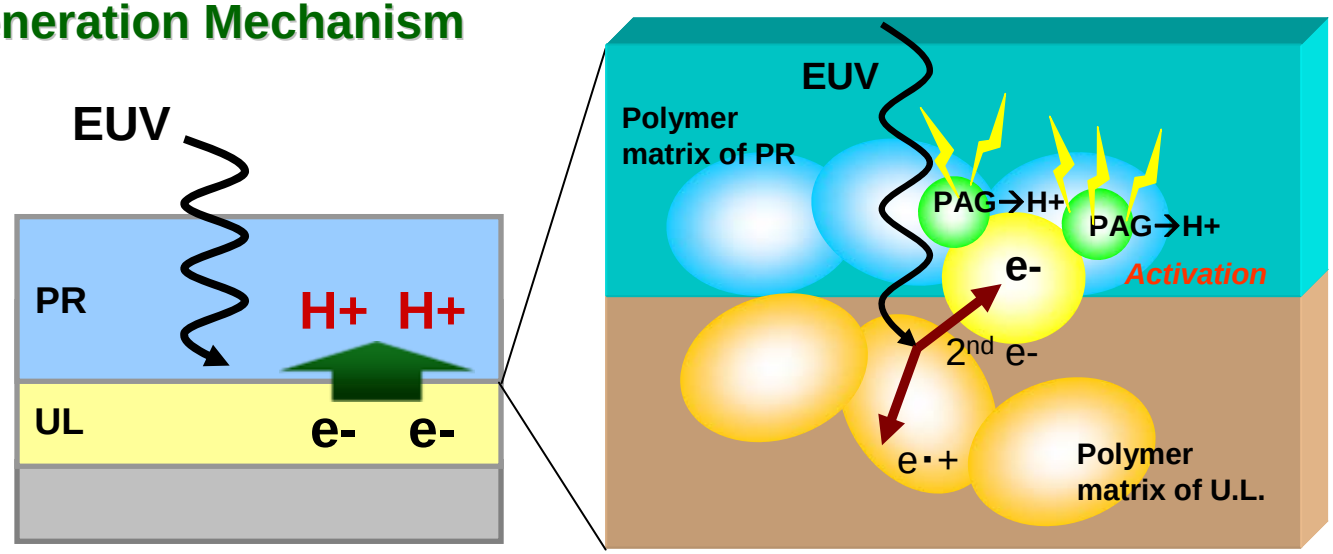
4 · Study of acid generation efficiency at PR/UL interface.

Further approach for LWR reduction and Sensitivity control

4. Study of acid generation efficiency at PR/UL interface.

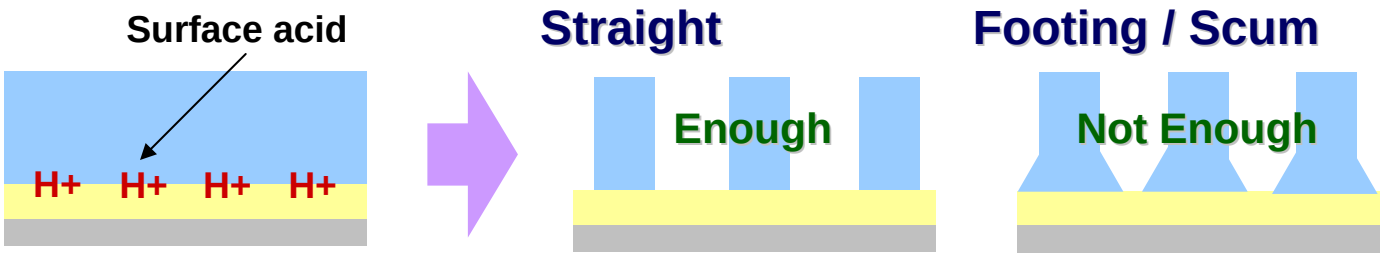
EUV
Challenging and Solution by x-layer

Acid Generation Mechanism



Acid is generated from electron that reacted by resin and EUV

UL Surface Acid Control

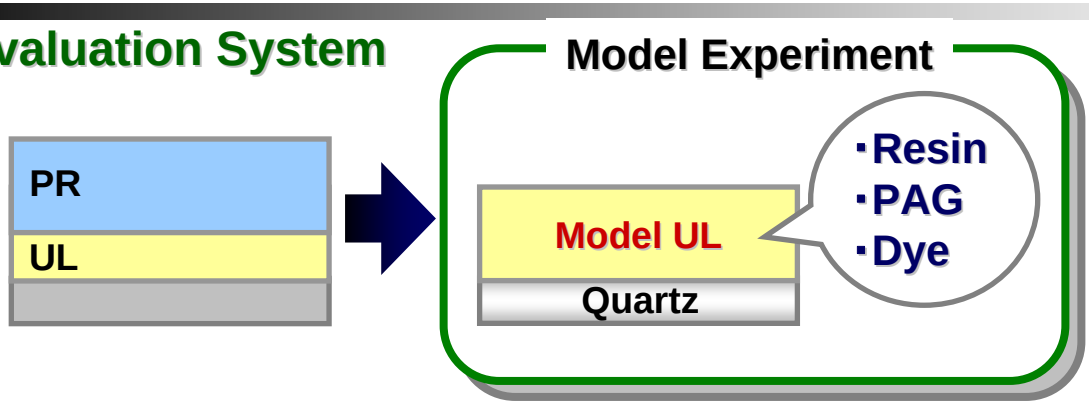


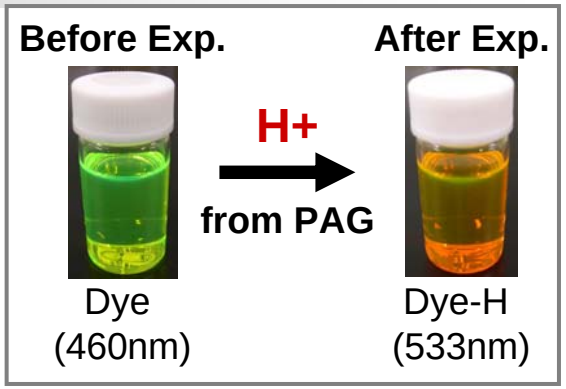
Acid concentration control of UL-PR interface is important to obtain good litho performance.

Experiment

EUV
Challenging and Solution by x-layer

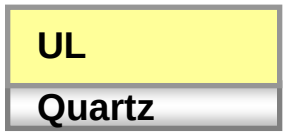
Evaluation System





Evaluation Method

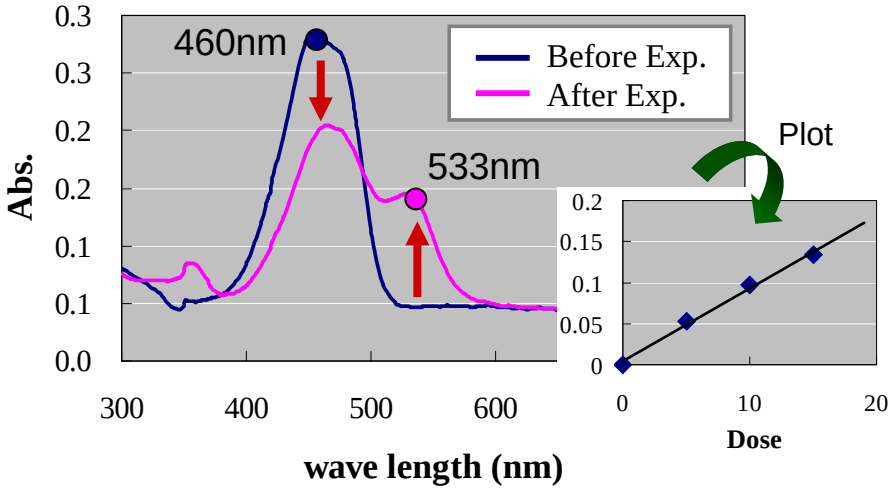
1. Model UL coat



2. EUV exposure

3. UV measurement

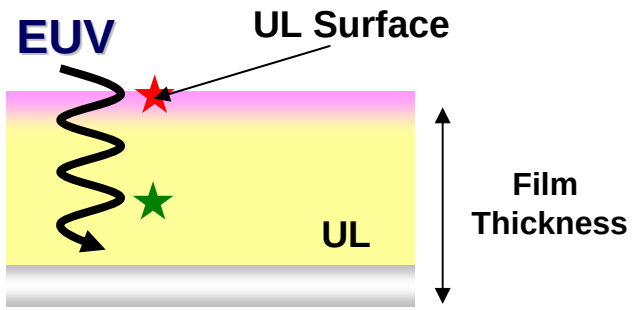
Experiment
@Osaka univ.



Measurement of changing absorbance
@533nm of dye in exposured area.

Experiment

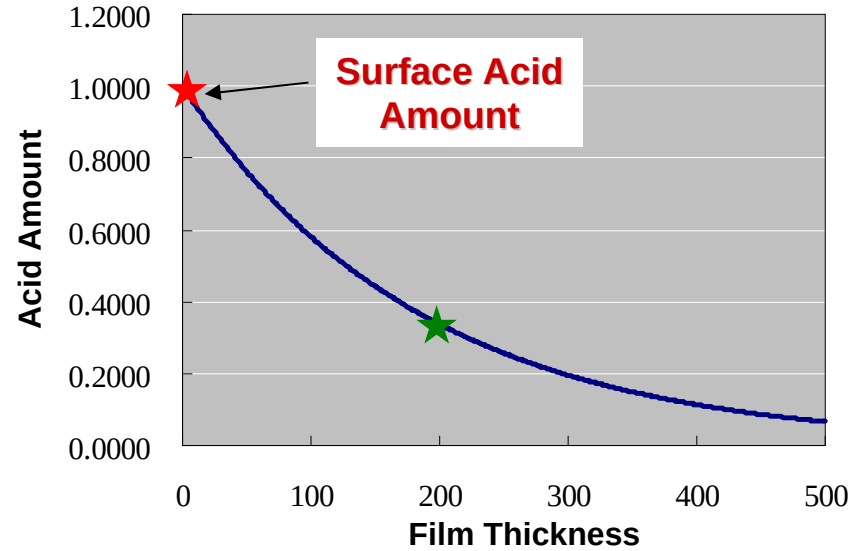
Surface Acid Amount Calculation



$$A=Q(1-e^{-\alpha x})$$

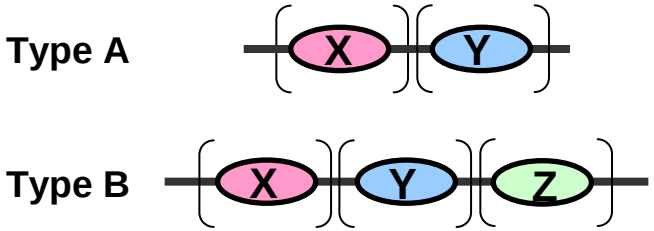
A: Total acid amount
Q: Quantum yield
α: Absorption efficient
x: Film thickness

Total acid amount can estimated uv measurement.



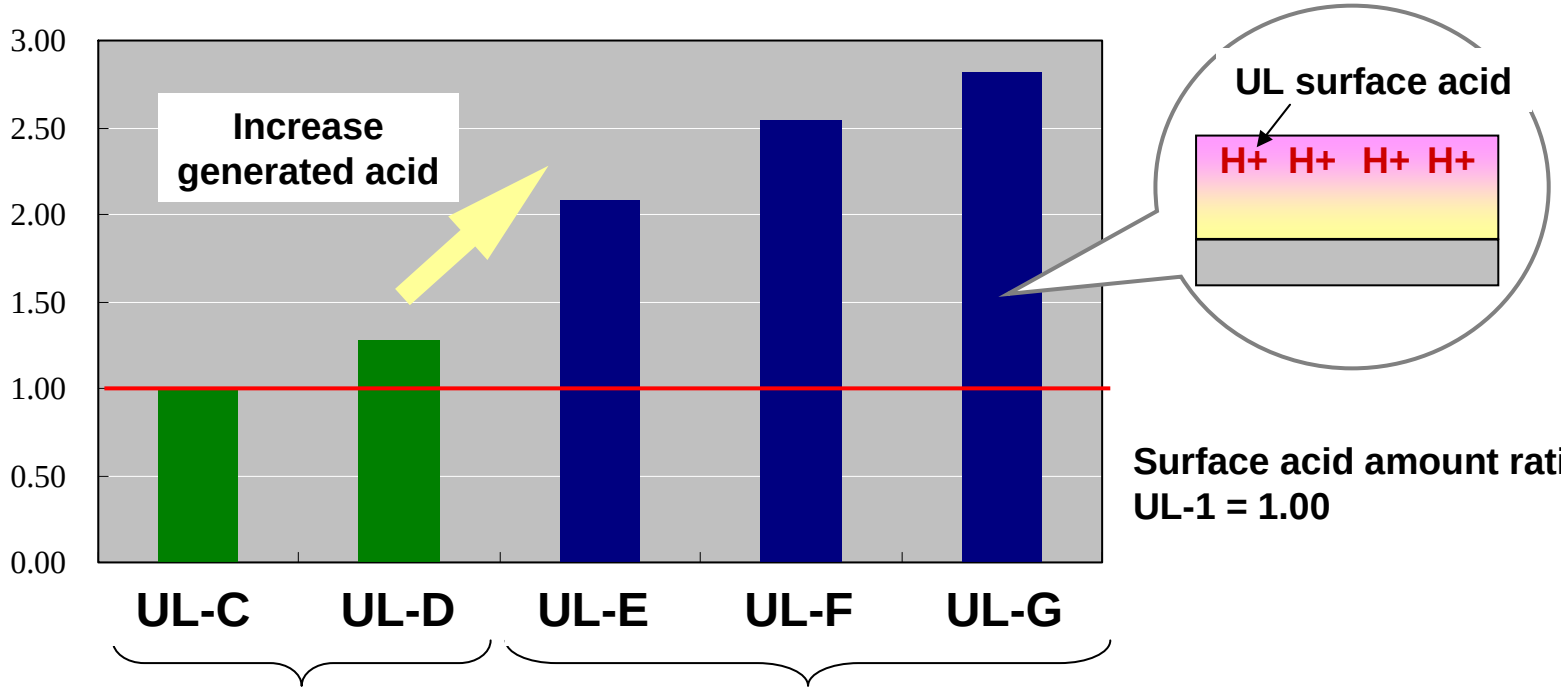
Evaluation Resin

Sample	Resin	X	Y	Z
UL-C	Type A	a	b	-
UL-D	Type A	c	d	-
UL-E	Type B	e	f	None
UL-F	Type B	e	f	g
UL-G	Type B	e	f	h



Result

Surface Acid Amount ~Model Experiment~



Surface acid amount ratio
UL-1 = 1.00

Type A

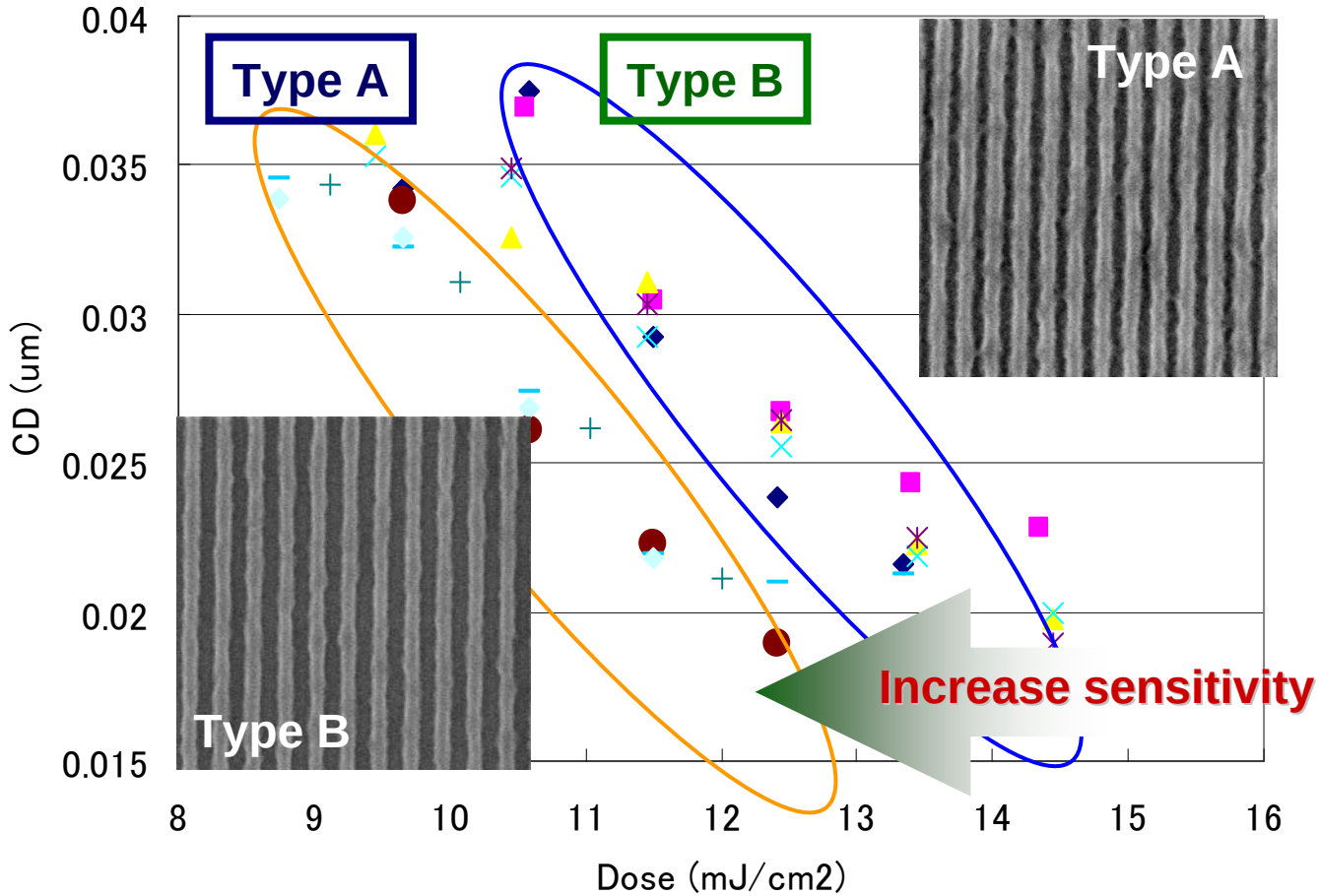
Type B

Type B can easily generate more electron by EUV.

Type B resin used UL can generate more acid in UL surface compared with type A resin from our model experiment.

EUV Litho Evaluation ~Dose to CD hp 30nm~

EUV
Challenging and Solution by x-layer



Tool: MET
Target CD: hp30nm

Type B resin used UL can improve sensitivity,
and pattern space area is more clear than type A resin from top view.
⇒ Type B resin generated more electron by EUV by EUV litho test
UL can control PR sensitivity and litho profile by UL chemical structure.

5. Investigation of Ultra thin UL

EUV

Challenging and Solution by x-layer

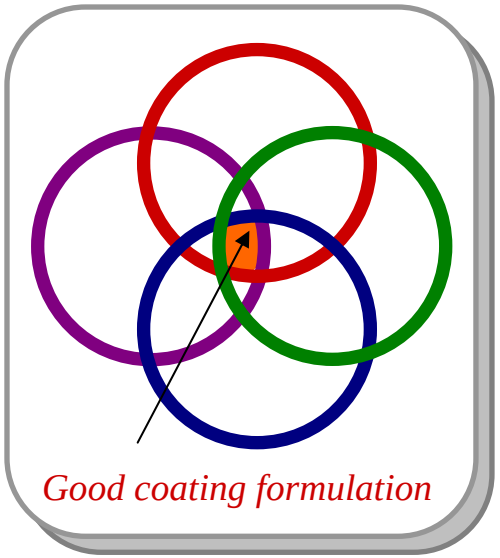
Key parameter for coating property

Solubility of resin

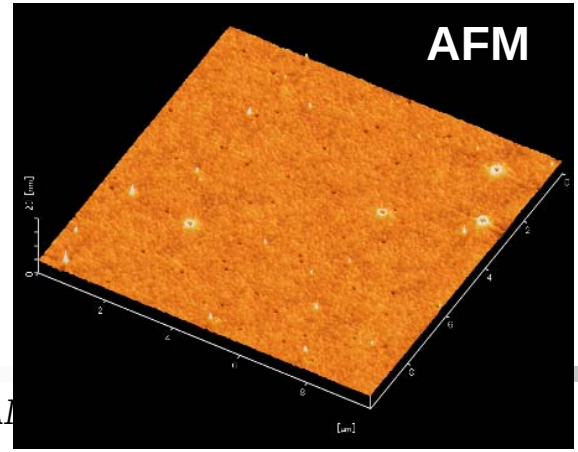
Hydrohobicity of the resin

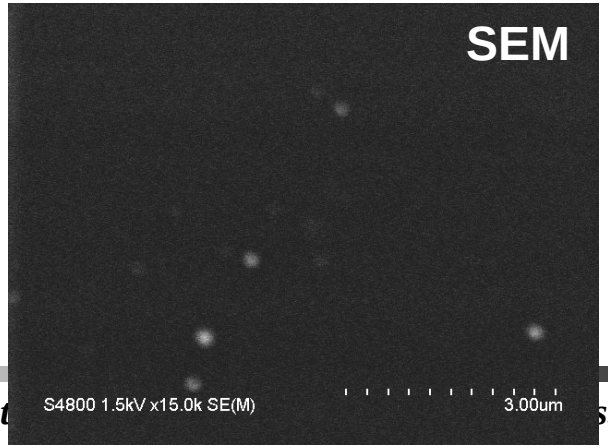
Solvent parameter

Solvent boiling point and viscosity



Pinhole on 5nm Thickness





NISSA

Elect

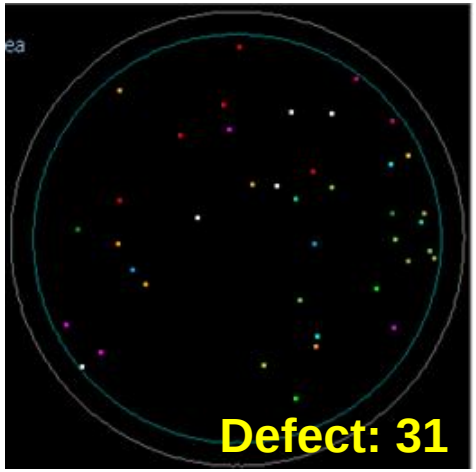
s.

Thickness effect for coating property

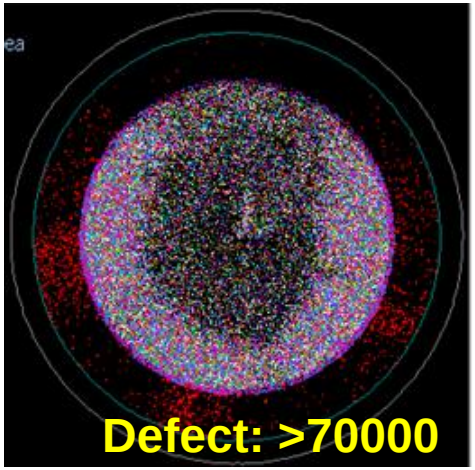
- *Hand dispense*
- *ACT-8 (TEL) STD recipe*
- *Sub. Bare-Si (8inch)*
- *SP1 (DLS)*
- *Inspection Size: >0.10um*

Worse Case

FT=100A



FT=50A

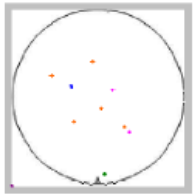
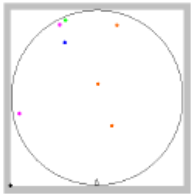
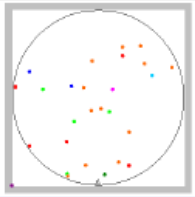
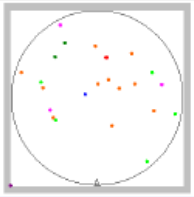


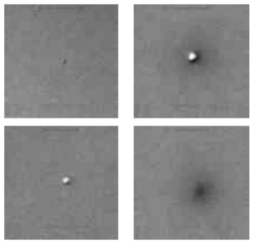
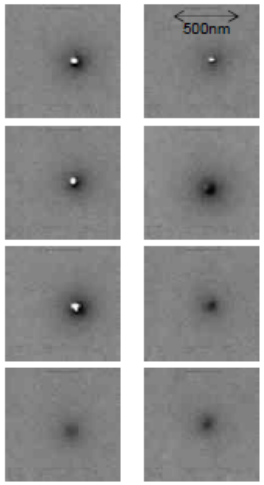
Coating defect

EUV
Challenging and Solution by x-layer

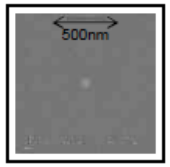
➢ **Measurement Tool**

- Coverage : VisEdge CV300@KLA
- Thickness : Spectra-Fx200(Spectroscopic ellipsometer)
- Top side defect : SP2,KLA2800@KLA , RS4000@Hitachi

	UL 10nm	UL 5nm
SP2 (Initial on Bare-Si)	 9	 7
SP2 (After UL coating)	 27	 23
SP2 (Adder particle)	19	19

	UL 10nm SEM visible: 4count Reviewed: 19count	UL 5nm SEM visible: 17count Reviewed: 19count
SEM Image		

Typical pinhole

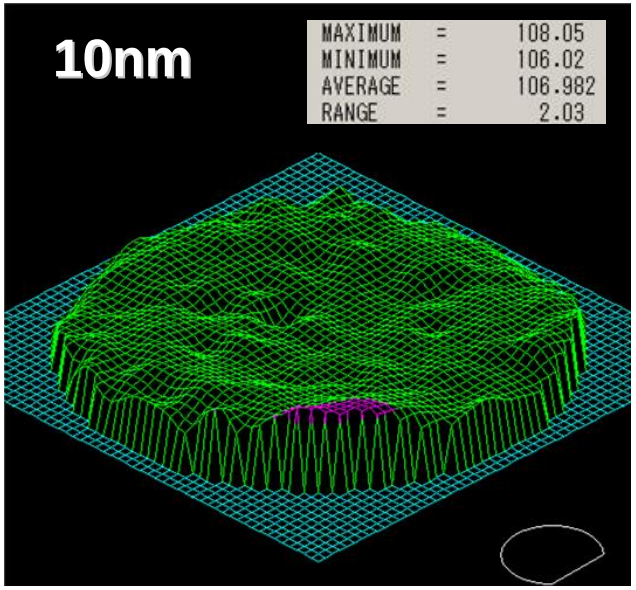


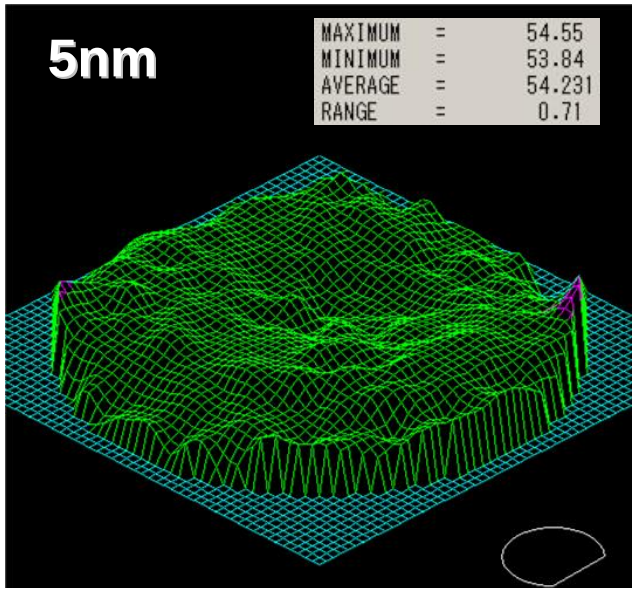
Optimized UL showed very good coating property even 5nm.

Thickness uniformity

EUV
Challenging and Solution by x-layer

- *Hand dispense*
- *ACT-8 (TEL) STD recipe*
- *Sub. Bare-Si (8inch)*
- *RE-3100 (DNS)*
- *FTK measurement*
  with 300points





Conclusion

1. The key parameter for EUV-UL development are Outgassing control, strong adhesion with PR and LWR control.

2. The result of acid generation efficiency at UL surface was roughly correlated with actual PR potospeed. (But need to confirm some other resist platform)

3. High density UL could make resist profile more vertical.

4. By controlling key parameter for coating property, 5nm FTK could be coated without any coating issue (uniformity, coating defect, etc..)