New challenging of breaking RLS-trade off for 1Xnm patterning by ultra thin Under Layer

Nissan Chemical Industries, LTD.

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Outline

- Introduction
- Developing status of ultra thin Org.UL
- Evaluation result of polymer additive and special additive (improving of LWR)
- Developing status of NTI UL (Next generation technology)
- Summary

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- **Introduction**
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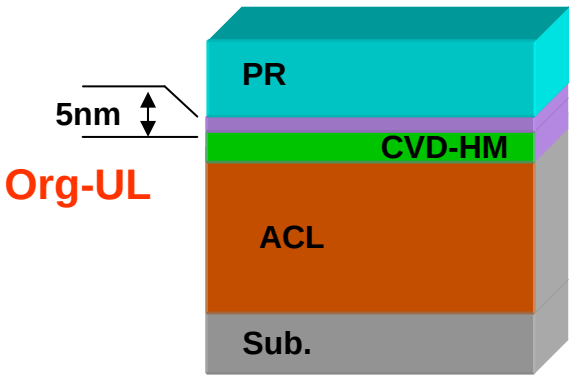
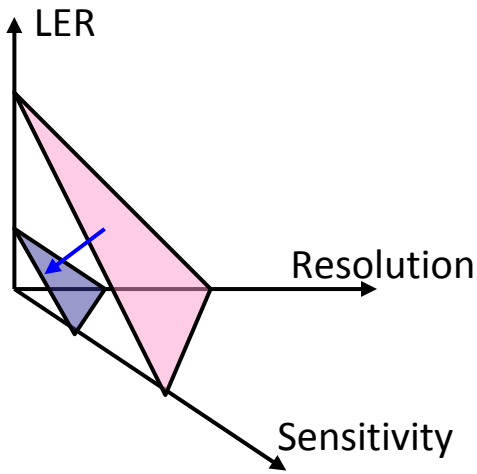
Purpose for applying Under Layer (UL) for EUV





Activity for UL:

- Optimization of resin design
- Film surface acidity control
- Acid or quencher diffusion control
- Defect control
- High adhesion for resist pattern

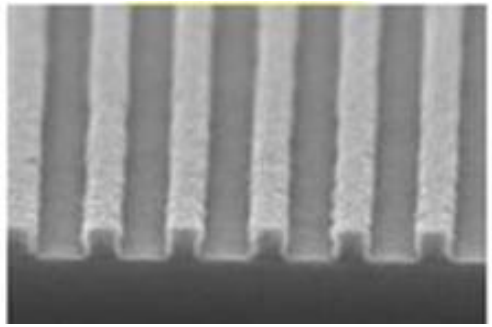
Help minimizing of RLS trade off by applying functional UL.

From the viewpoint of etching, the thinner FTK UL has been required with the decreasing of PR FTK at smaller pattern.

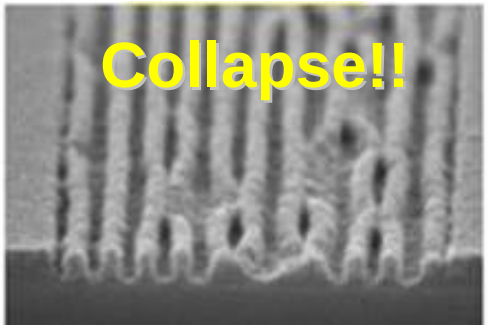
Merit of the applying UL

➢When resist pattern is minimized, pattern collapse occurs.

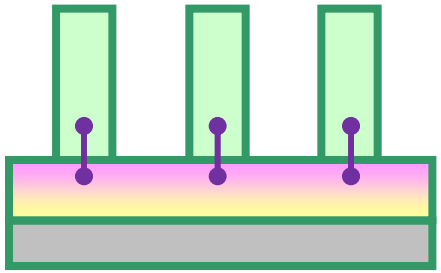
hp 50nm



hp 25nm

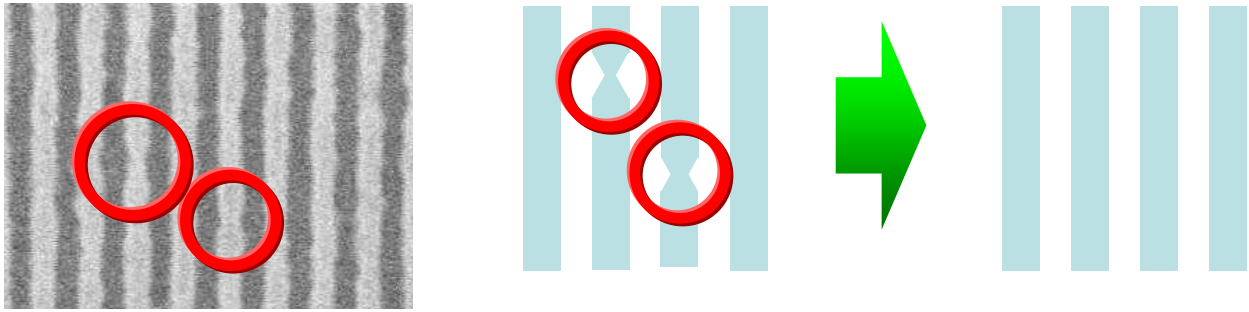


Keep standing, fine patterning



Pattern collapse is prevented by applying UL.

➢Photon shot noise occasionally affects LWR at EUV.

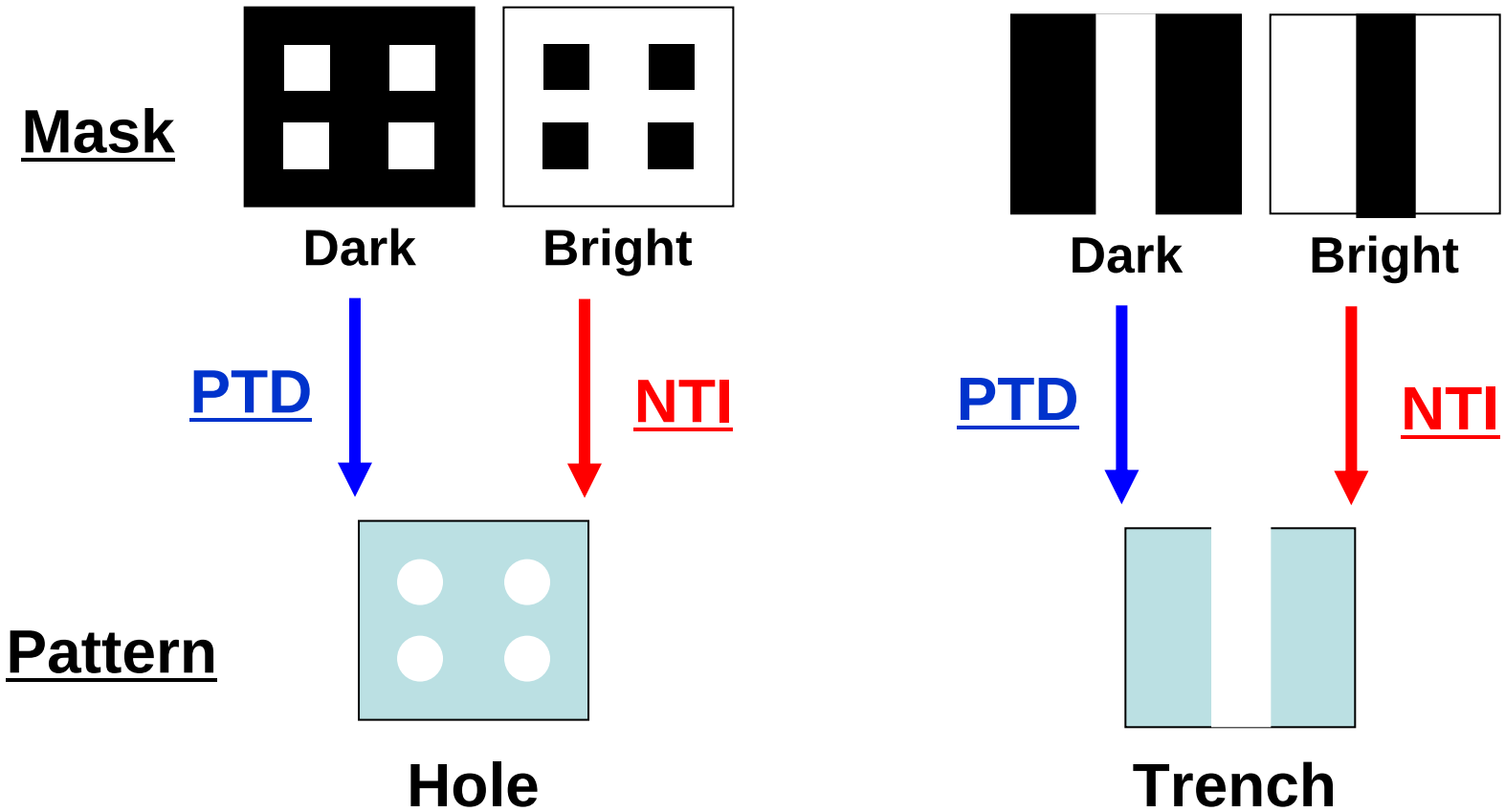


We expect LWR is reduced by applying UL.

We are developing UL in consideration of these issues simultaneously.

Our motivation for NTI process

➢We are developing NTI UL for next generation technology.



NTI process has some advantages, because dark mask can be applied for bright patterning. And NTI process is designed for high resolution technology like ArFi.

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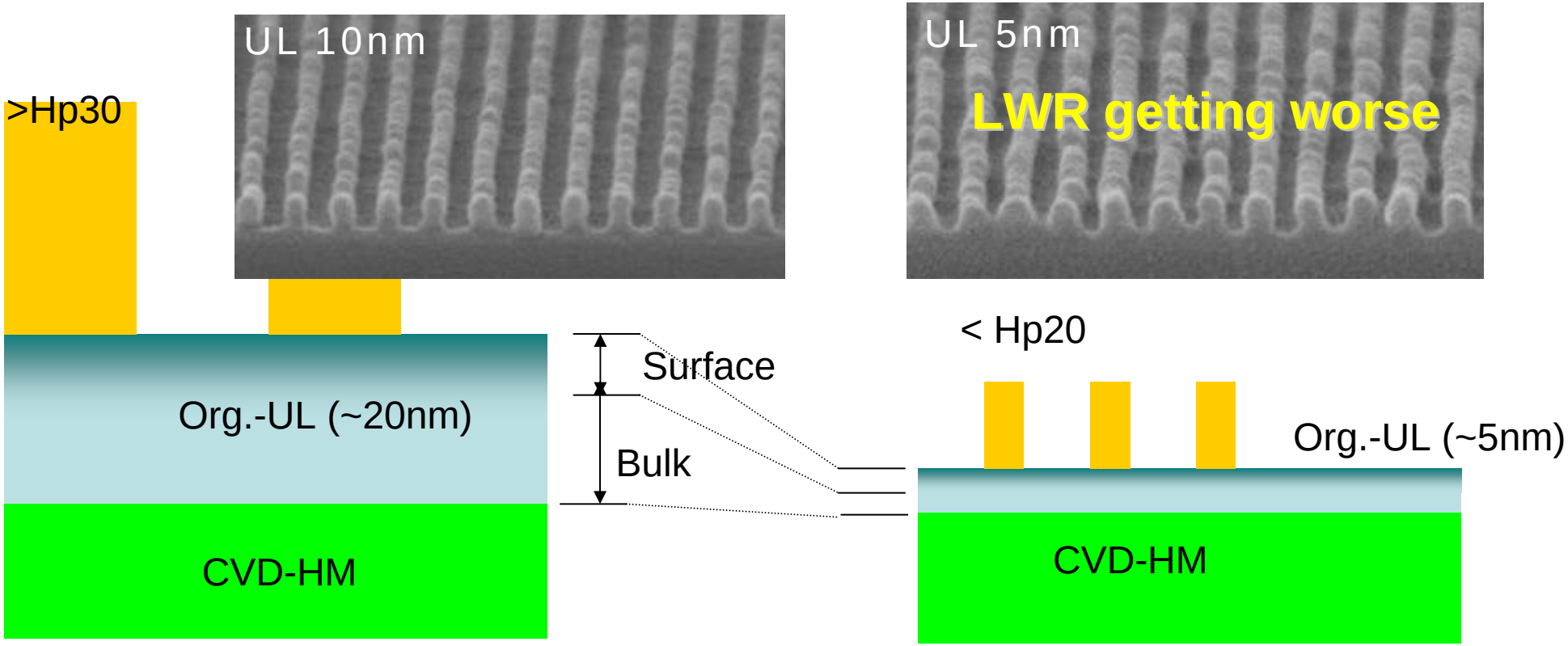
Issue of ultra thin UL

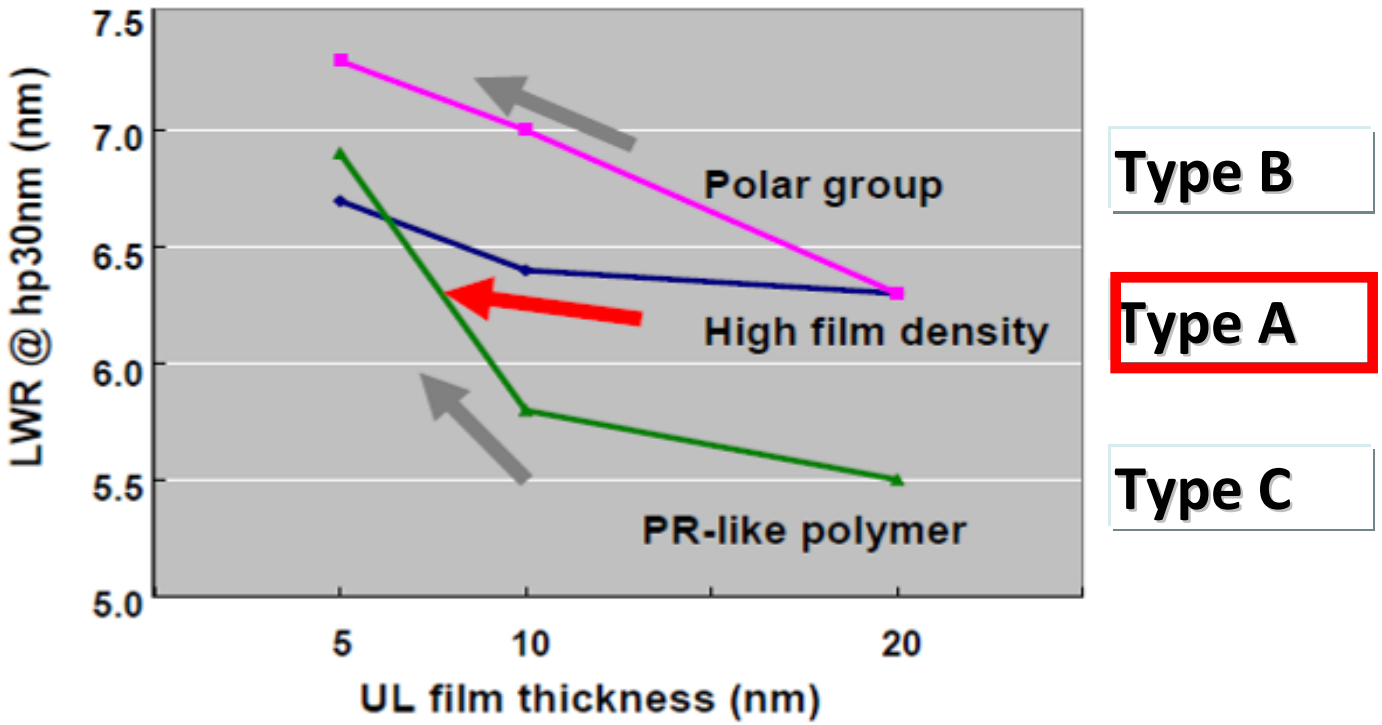


Ultra thin UL changes bulk and surface property compared with thick one.
LWR was worse with thinner thickness UL.

UL film thickness dependency about LWR at EUV

NEXL™
Challenging and Solution by x-layer

LWR on several thickness UL

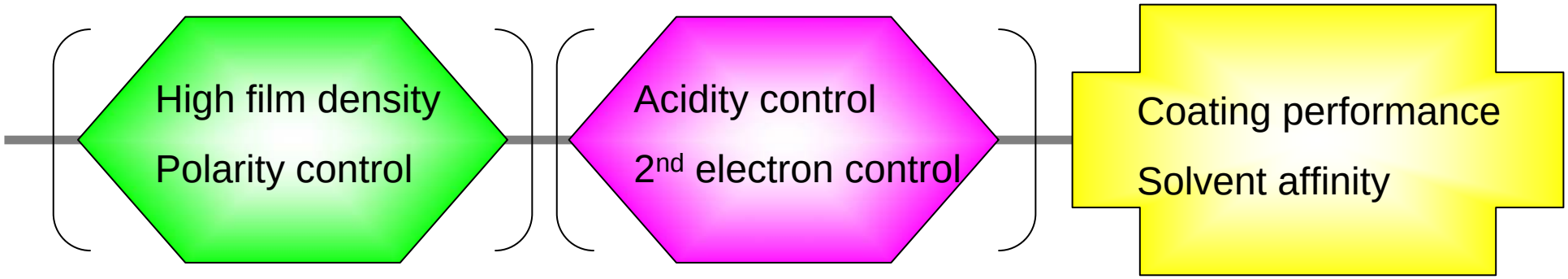


LWR got worse as UL became thinner.
High film density UL (TypeA) showed relatively stable compared with others.

Org.UL developing concept

Requirement for ultra thin UL(5nm)

- Good coating properly without pinhole, good uniformity and good step coverage.
- Good lithography performance. (Control of resist profile, LWR, PW and resist universality)
- Good etching performance. (First etching rate vs PR)



Sample concept for current UL (Type A)

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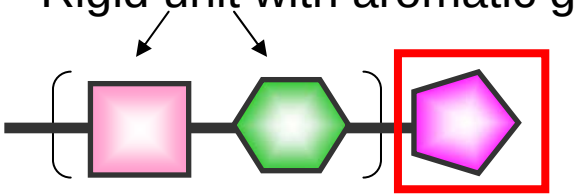
Challenging and Solution by x-layer

➢High film density was necessary for developing ultra thin UL(5nm).

NCX1630

Polyester type

Rigid unit with aromatic group



Coating property improving unit

Optimizing of solvent affinity

➢**Resist universal type**
➢**Good coating property**

ER=1.4 times of PR.

Film density about 1.34 g/cm^3

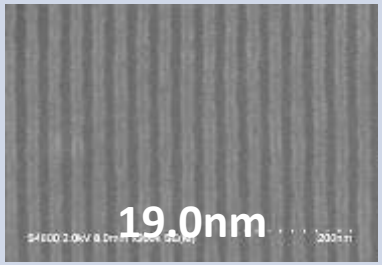
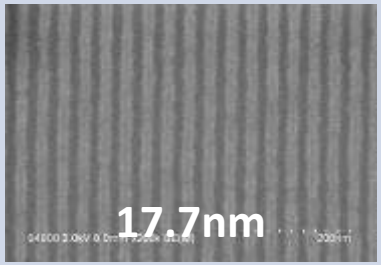
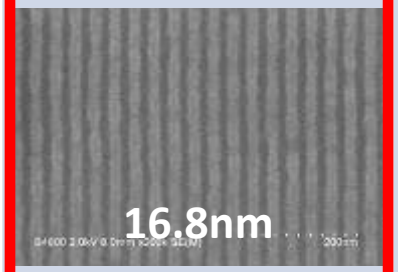
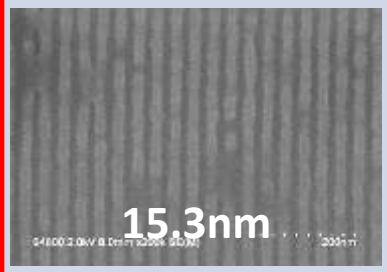
NCX1630 is keeping the balance of several property for ultra thin UL.

EUV lithography performance of NCX1630 at 1Xnm

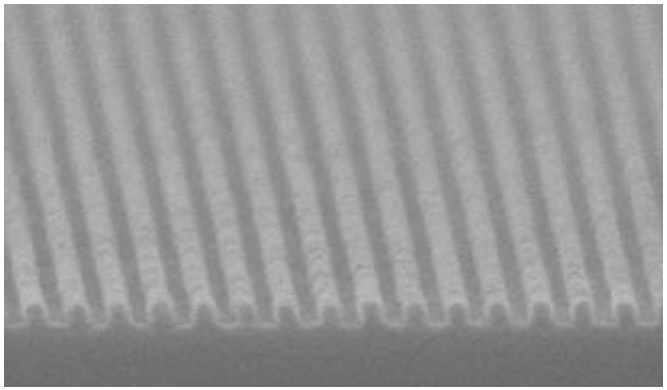
NEXL™
Challenging and Solution by x-layer

SEMATECH

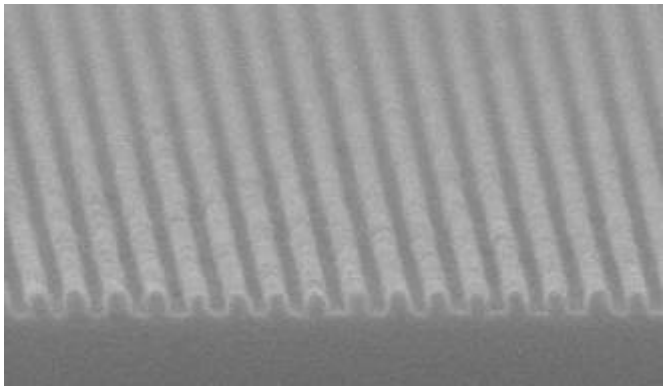
UL: NCX1630: 5nm
PR: 35nm

	hp19	hp18	hp17	hp16
NCX1630	 19.0nm	 17.7nm	 16.8nm	 15.3nm

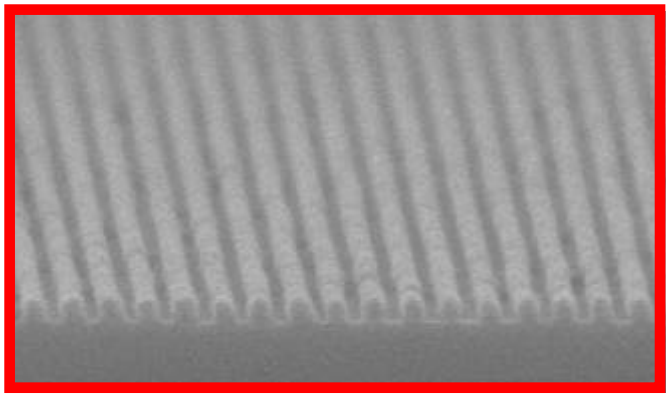
hp19



hp18



hp17



NCX1630 showed fine pattern at hp17nm.

UL thickness dependency of EUV lithography

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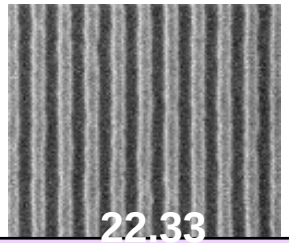
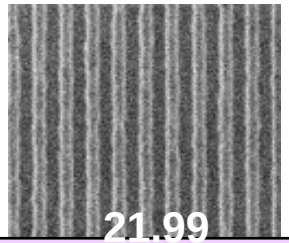
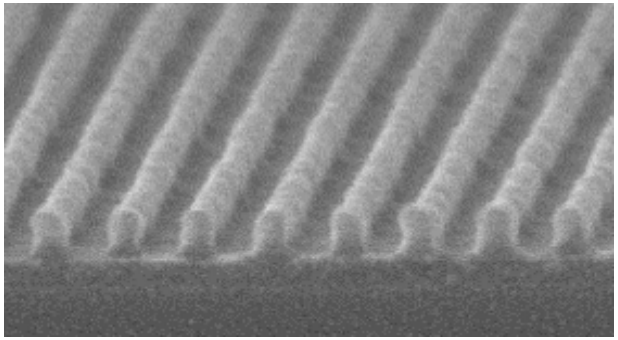
Challenging and Solution by x-layer

imec

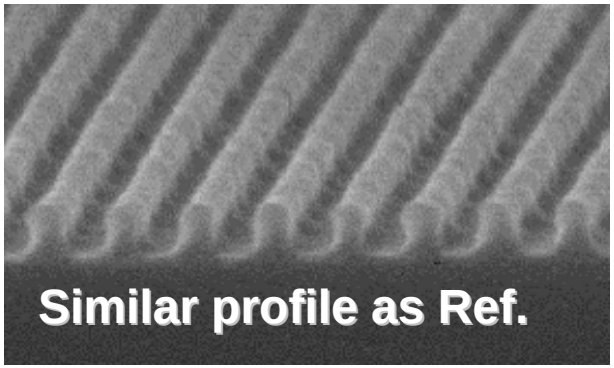
NXE3100
NA0.25, Dipole60X, 0.81/0.43

Parameter	Ref.(20nm)	NCX1630(5nm)
hp22 (PR40nm)		
Dose to size, my	18.1	17.0
LWR nm	4.6	4.8
DOF at 10% EL	0.30	>0.32
Ultimate resolution	18.6	<18.6

PR(40nm)
Ref.(20nm)



NCX1630(5nm)



Except for LWR, Lithography performance of NCX1630(5nm) is better than Ref.UL(20nm).

LWR reduction and improving adhesion are necessary for 1X nm patterning!!

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Polymer additive for UL

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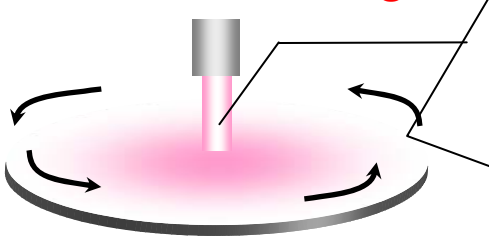
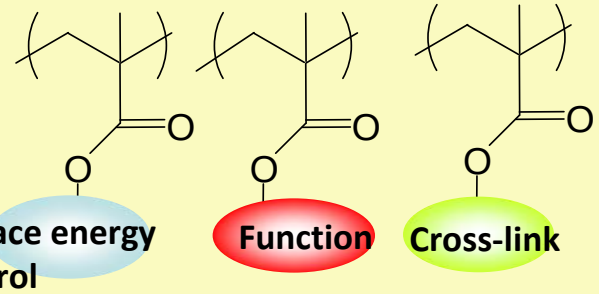
Challenging and Solution by x-layer

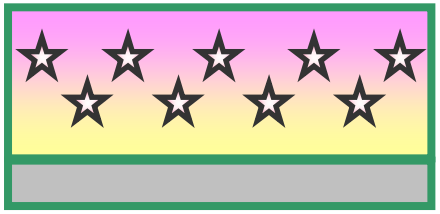


UL coating on the Substrate

Concept

☆☆ Surface Control Additive (=SCA)



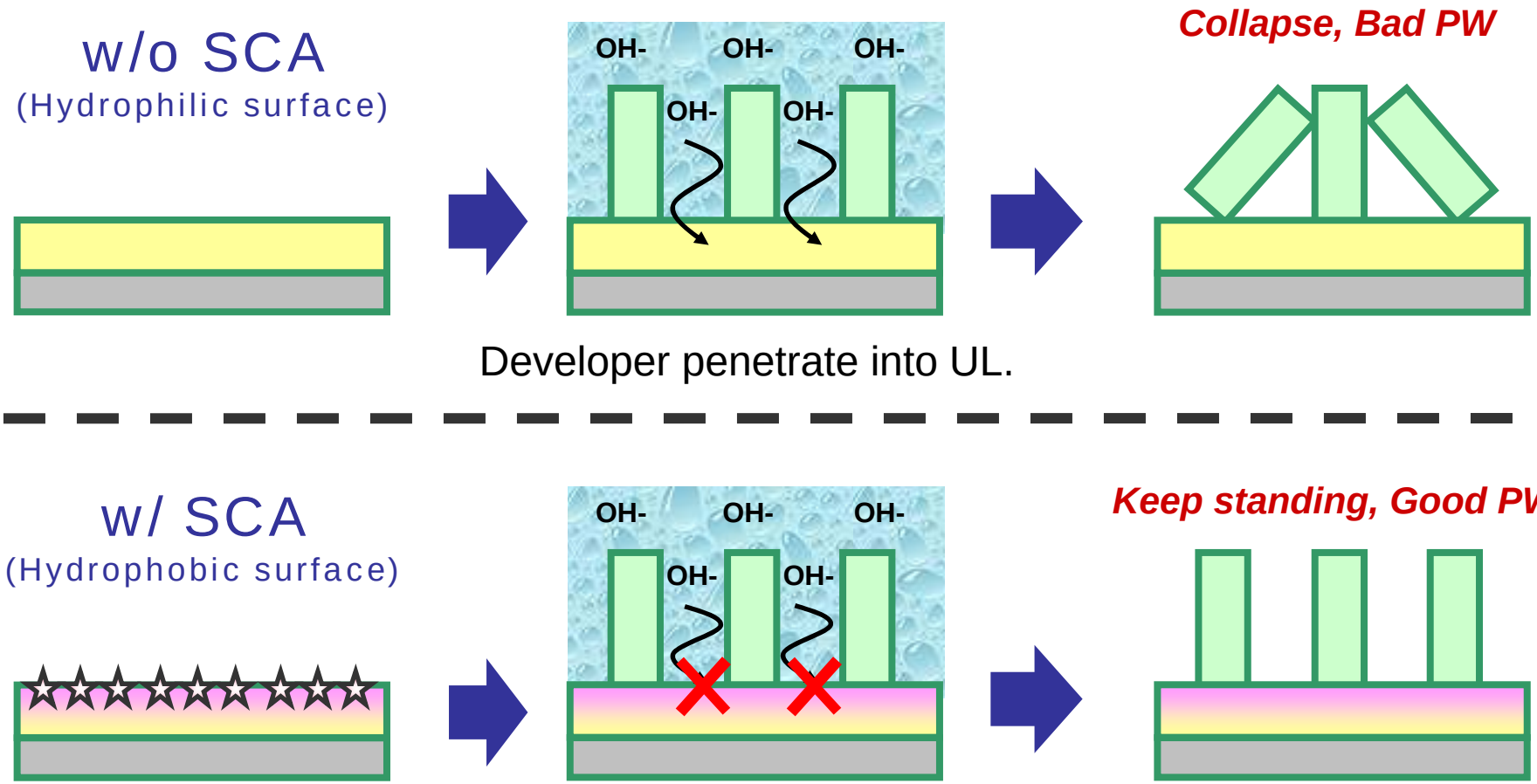


SCA move to UL surface after coating.

Improve adhesion between PR/UL by control the surface acidity or hydrophobicity, etc.

We can optimize the UL property with applying several types of SCA.

Concept of SCA



SCA can prevent from penetration of developer into UL and improve pattern collapse.

SCA concept of high adhesion and LWR reduction

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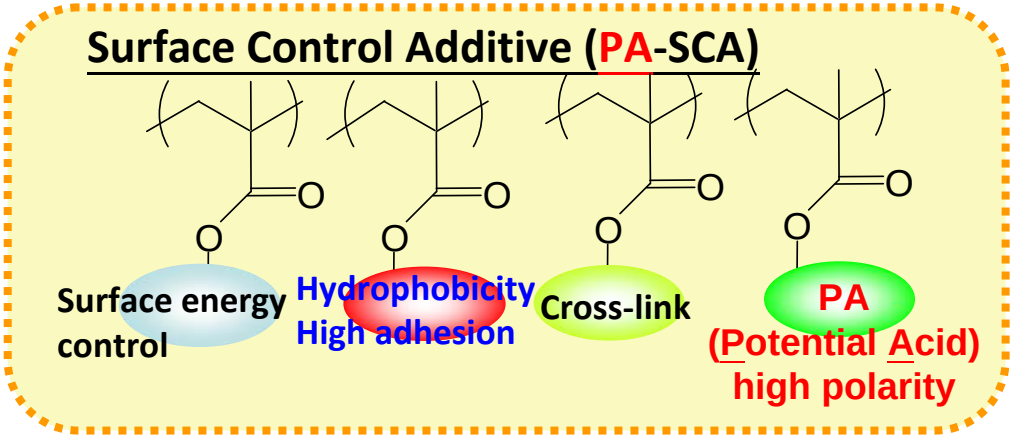
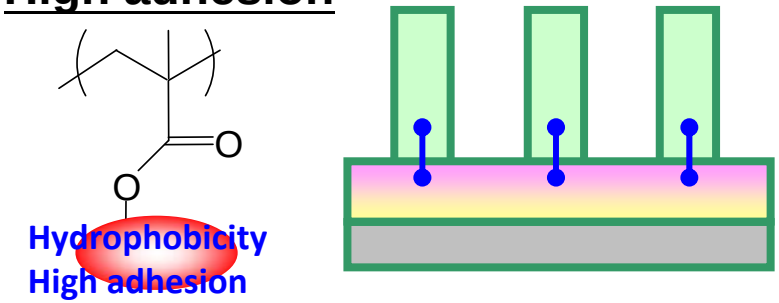
Challenging and Solution by x-layer



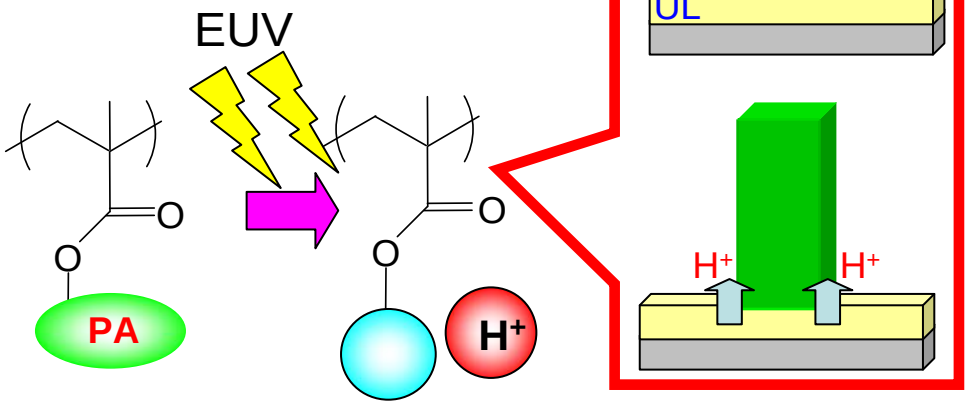
High adhesion



Interaction with PR polymer by hydrophobic interaction

High resolution

(LWR reduction)



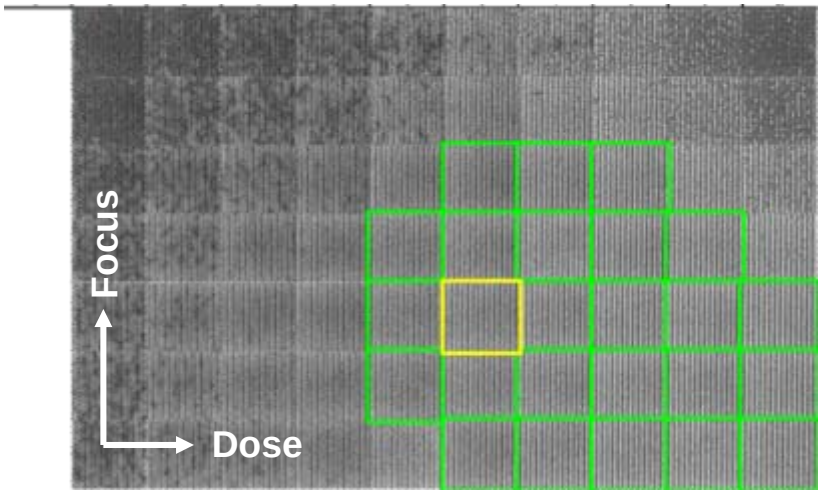
PA unit decompose after EUV exposure and generate acid directly.

Lithography performance at EUV

SEMATECH

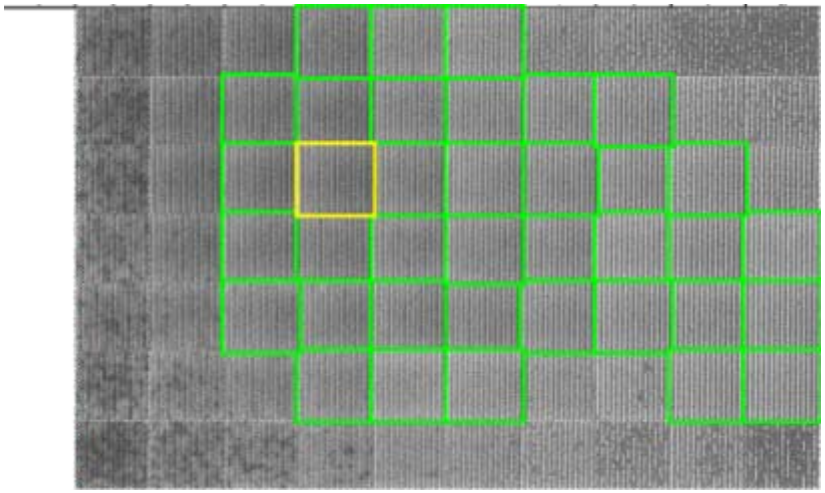
0.30NA, 0.93/0.36s
PR: 50nm, UL: 5nm
hp 24nm

NCX1630 (hp24nm) (C.A.(H2O)58.9°)

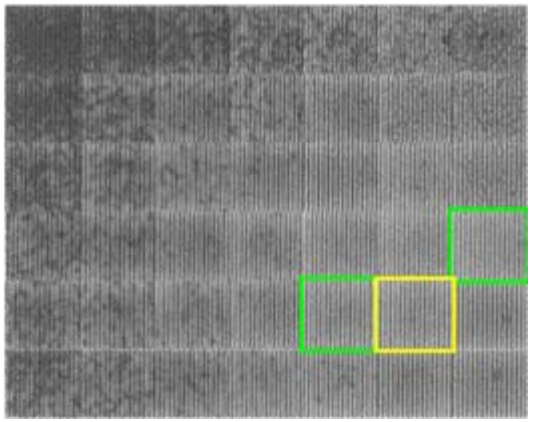


hp22nm

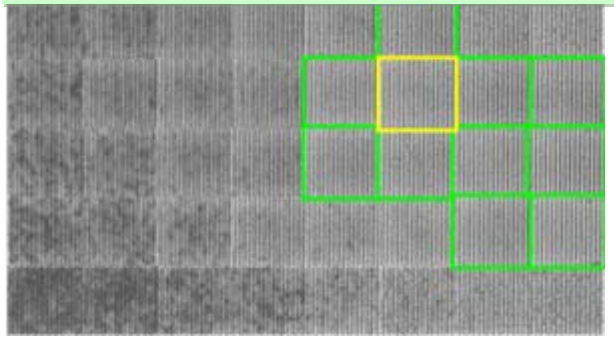
W PA-SCA (hp24nm)(C.A.(H_2O)70.8°)



hp22nm



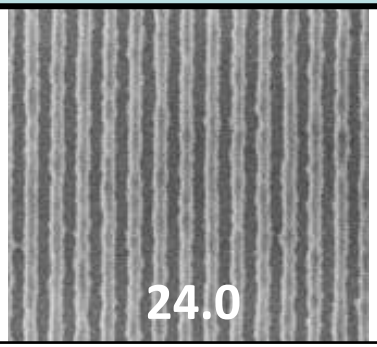
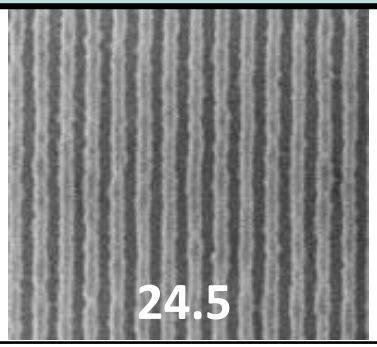
PW was improved dramatically at hp22nm



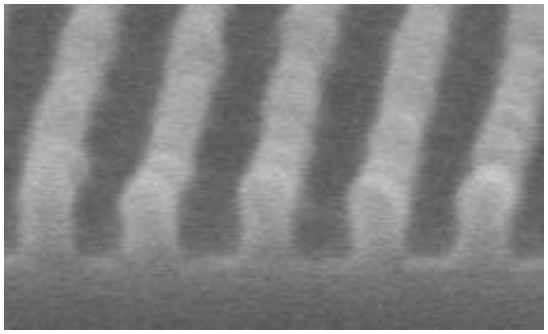
Lithography performance at EUV

SEMATECH

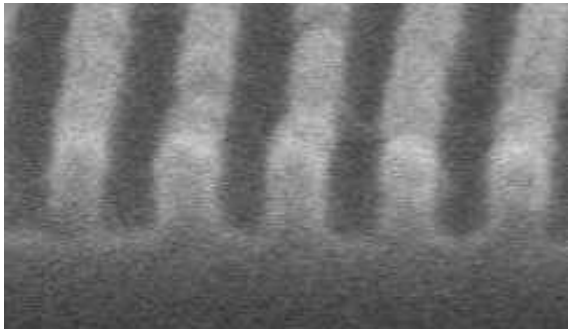
0.30NA, 0.93/0.36s
PR: 50nm, UL: 5nm
hp 24nm

Item	NCX1630 (Ref.)	w/ PA-SCA
Top view hp24nm		
Dose (mJ/cm^2)	16.5	16.5
LWR (nm)	4.3	4.1
DOF(nm)	200<	250<
MaxEL%	15.7	18.6
MCD (nm)	21.0	20.4

NCX1630 (hp24nm)



W/PA-SCA



UL (w/ PA -SCA) showed better lithography performance than Ref.

Lithography performance at 1Xnm

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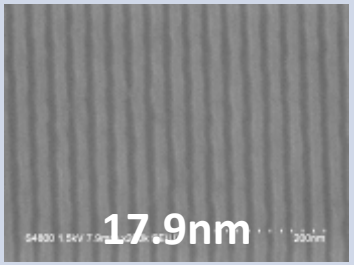
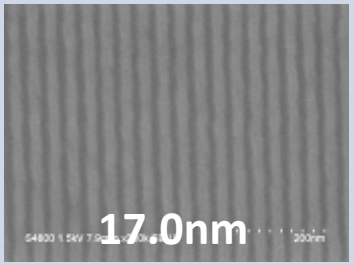
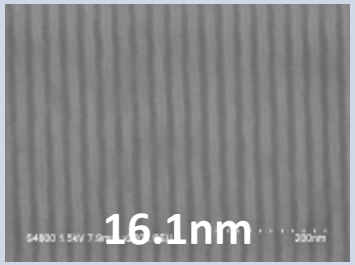
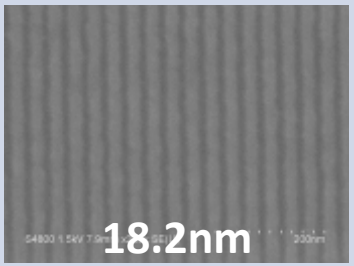
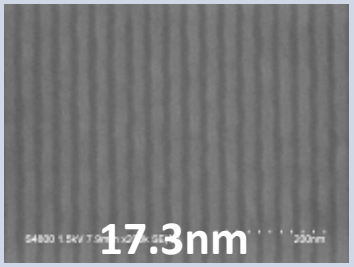
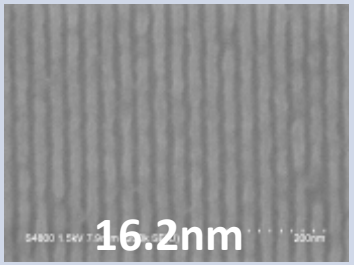
Challenging and Solution by x-layer

SEMATECH

UL: 5nm
PR: 35nm

	hp18	hp17	hp16
NCX1630	 17.9nm	 17.0nm	 16.1nm

	hp18	hp17	hp16
W/PA-SCA	 18.2nm	 17.3nm	 16.2nm

UL(W/PA-SCA) showed fine pattern at hp17nm.

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Special additive concept for improving LWR

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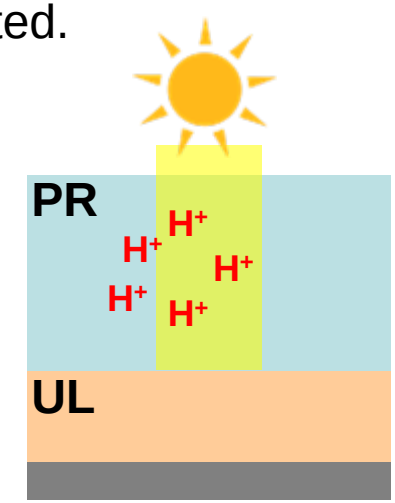
Challenging and Solution by x-layer

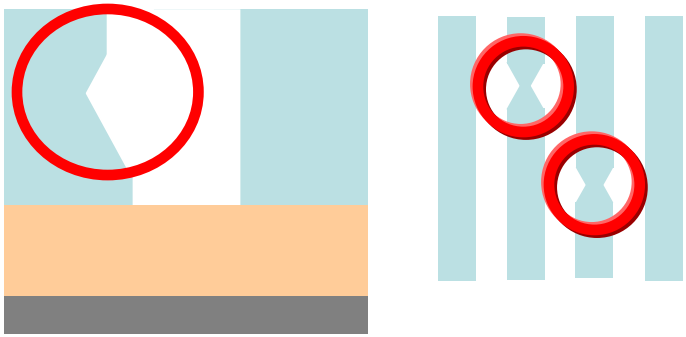
Concept of special additive

- Buffer effect
- Sensitivity is not affected.
- Improving of PW



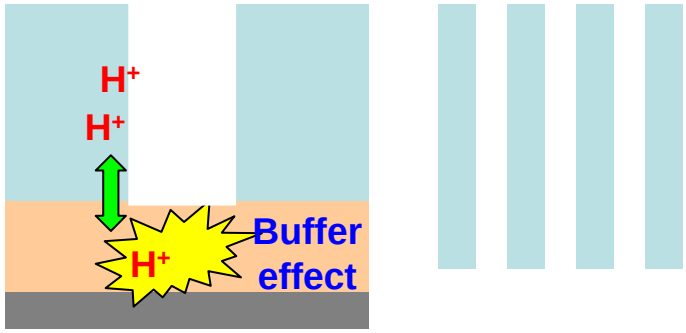
Photon shot noise causes partially excess acid after EUV exposure.

W/O special additive



Excess acid affects the resist profile.

W/ special additive



UL (w/special additive) can neutralize the excess acid generated partially by photon shot noise and improve LWR.

Lithography performance at EUV

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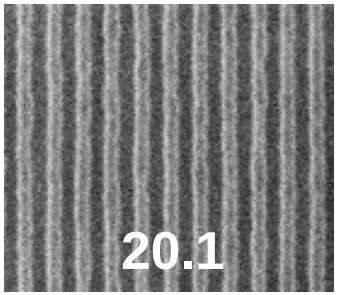
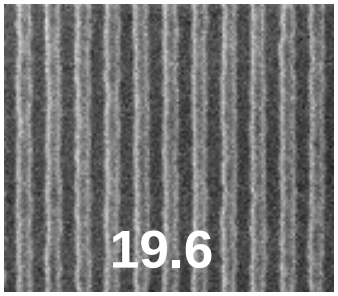
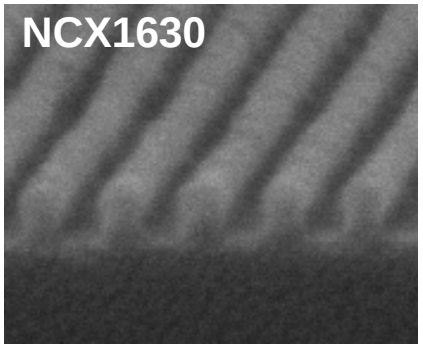
Challenging and Solution by x-layer

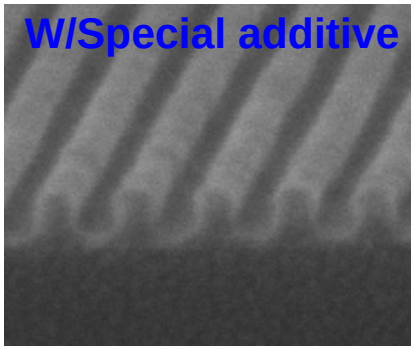
Parameter	NCX1630	W/Special additive
hp20		
Dose to size, mJ	18.0	17.8
LWR nm	5.3	5.0
DOF at 10% EL	0.23	0.22
Max EL, %	17.4	26.0

imec

NXE3100

NA0.25, Dipole60X, 0.81/0.43





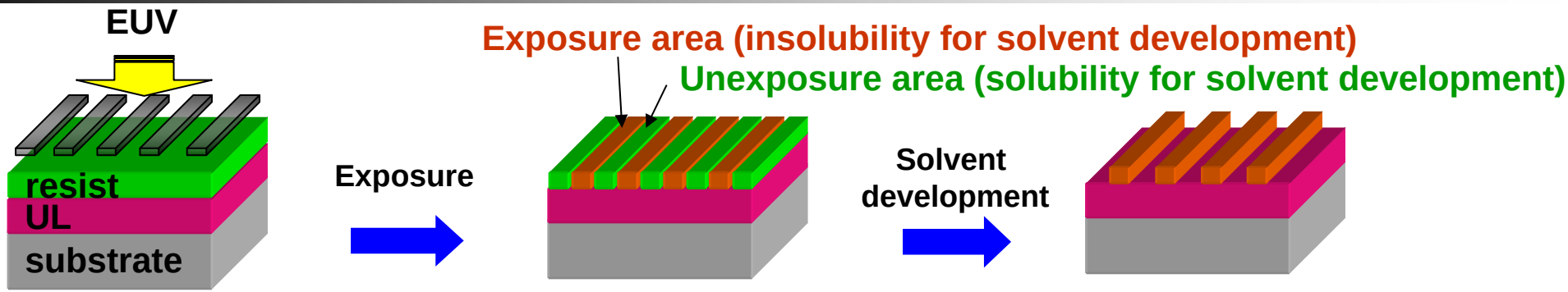
UL(W/ special additive) improved LWR.

Outline

- Introduction
- Developing status of ultra thin Org.UL
- Evaluation result of polymer additive and special additive (improving of LWR issue)
- **Developing status of NTI UL (Next generation technology)**
- Summary

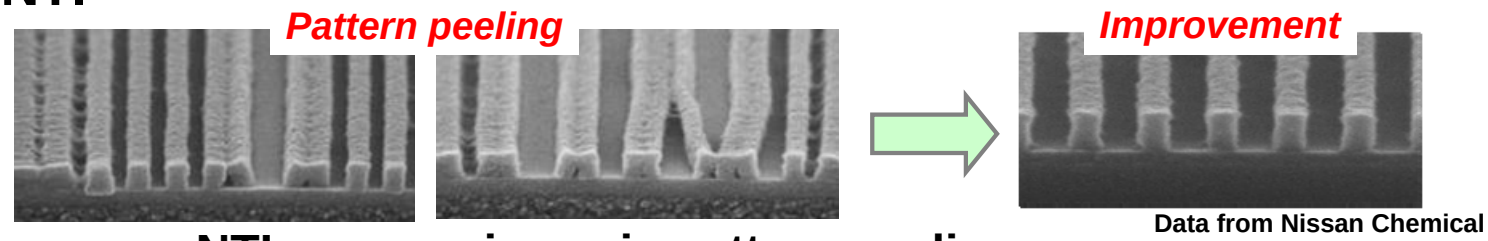
NTI process and issue

NEXL™
Challenging and Solution by x-layer



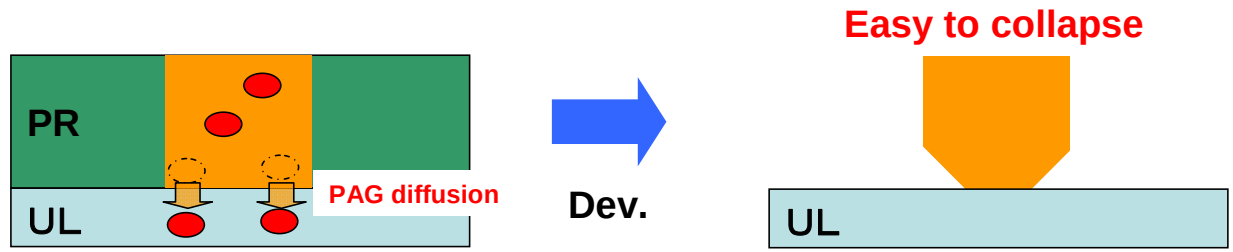
Un exposure area dissolve by solvent development in NTI process.

Issue of NTI



Data from Nissan Chemical

NTI process issue is pattern peeling.



Preventing of PAG diffusion is important factor for adhesion.

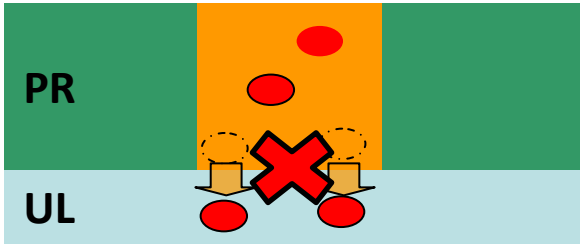
It is important to apply a rigid polymer structure and high adhesion UL.

Development concept for NTI UL

NEXL™
Challenging and Solution by x-layer

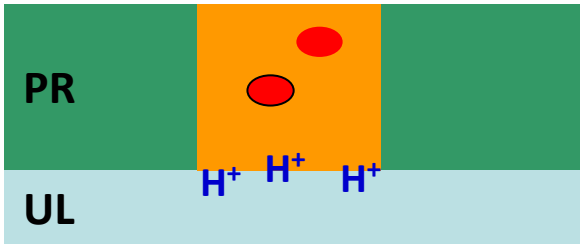
PAG

Concept 1

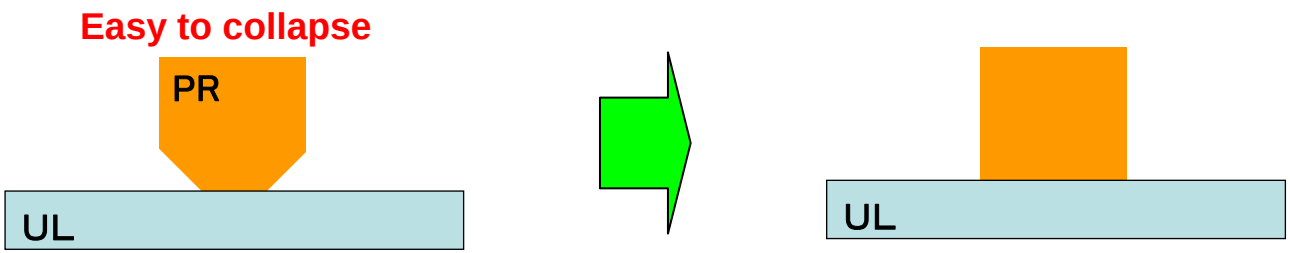


Prevent PAG diffusion by Rigid resin

Concept 2



Acid assist from UL

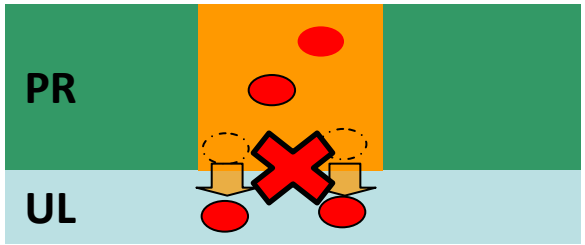


We focused on two concept for developing NTI UL in order to improve adhesion and resist profile.

Candidate of NTI UL

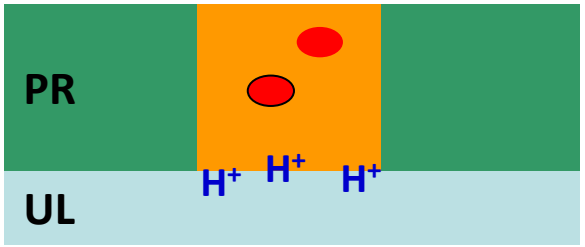
NEXL™
Challenging and Solution by x-layer

Concept 1



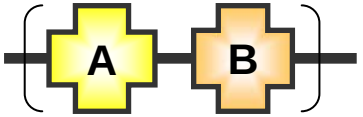
Prevent PAG diffusion by Rigid resin

Concept 2

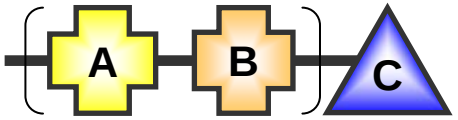


Acid assist from UL

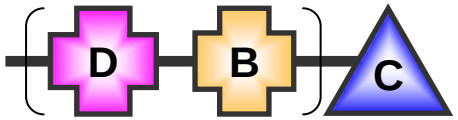
NTI UL①



NTI UL②



NTI UL③



High Adhesion

Surface acidity enhancement

Potential Acid unit

Surface acidity

New secondary electron unit

Surface acidity enhancement
High adhesion

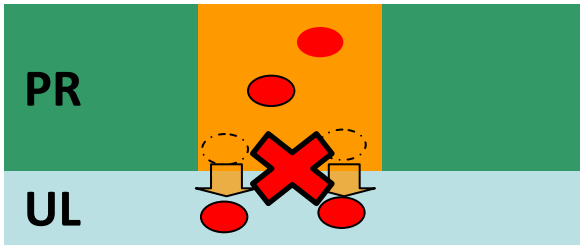
Rigid structure

NTI UL have been developed based on 2 concepts for achieving high adhesion and fine pattern in NTI process.

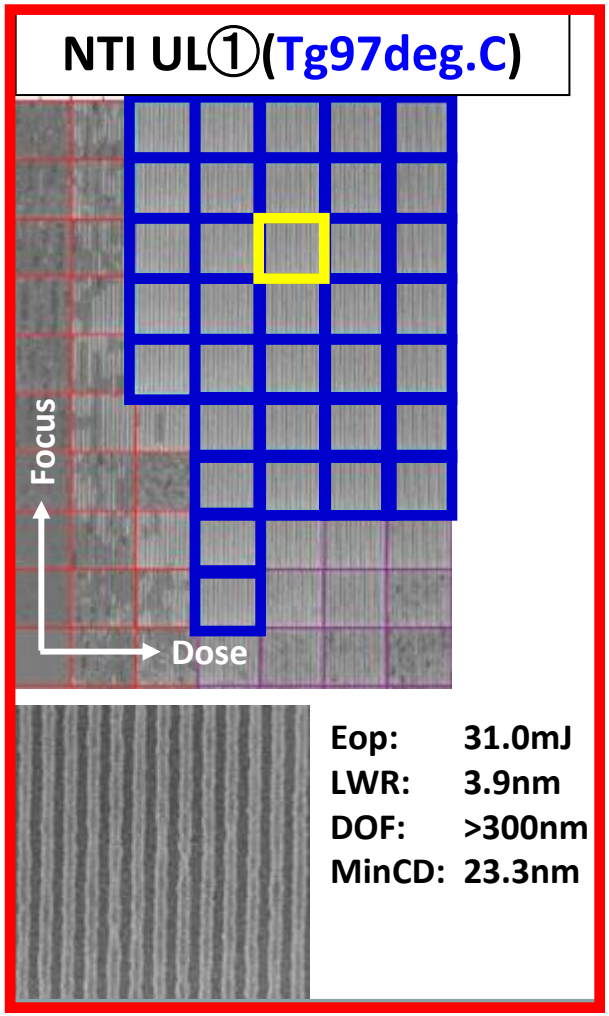
Concept1: PAG diffusion prevention

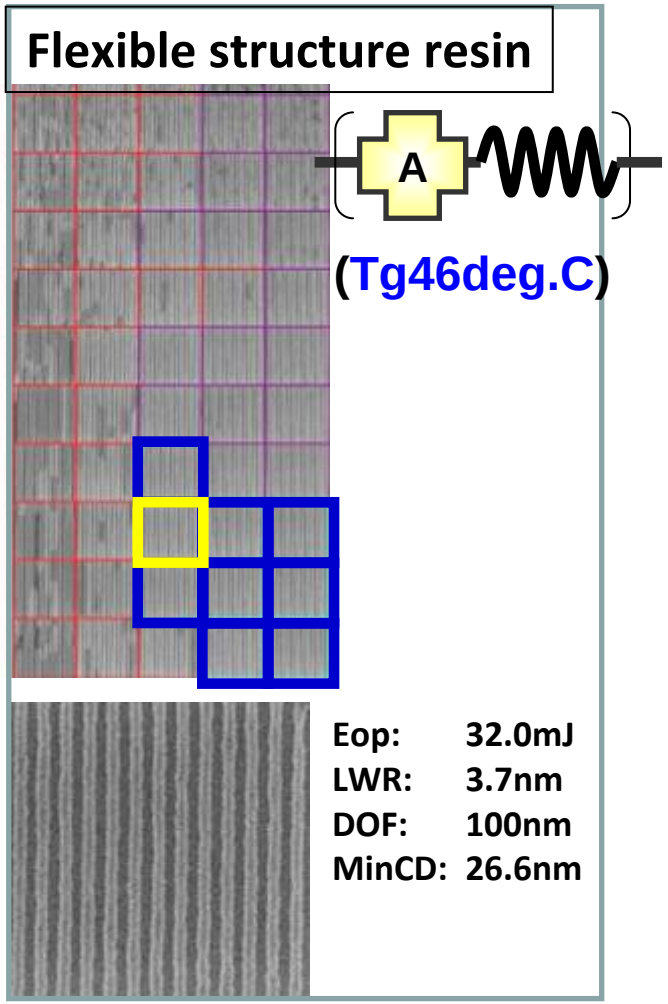
NEXL™
Challenging and Solution by x-layer

Concept 1



Prevent PAG diffusion by rigid structure resin



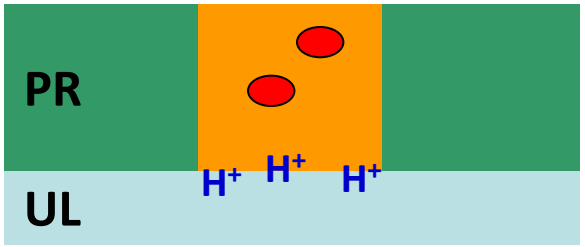


Rigid structure UL(NTI UL①) achieved wider PW than flexible one in NTI process.

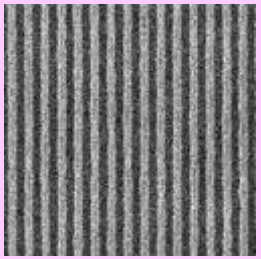
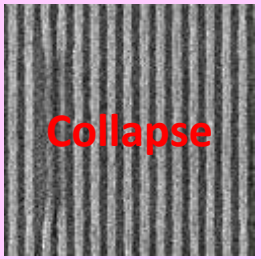
Concept2: Acid assist

NEXL™
Challenging and Solution by x-layer

Concept 2



Acid assist from UL

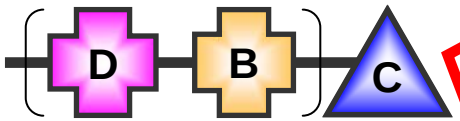
Sample	Acid assist	Non-assist
Top view hp22nm		
CD (nm)	22.5	23.4
Dose (mJ/cm^2)	18.0	18.0
LWR (nm) @ hp25	3.7	4.2

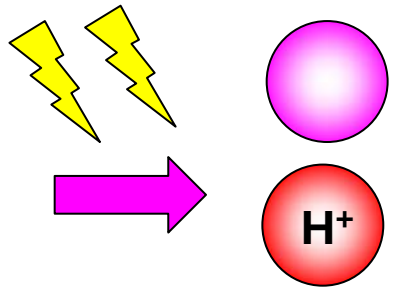
Acid assist UL achieved fine and smooth pattern in NTI process.

Analysis of potential acid unit after EUV exposure

NEXL™
Challenging and Solution by x-layer

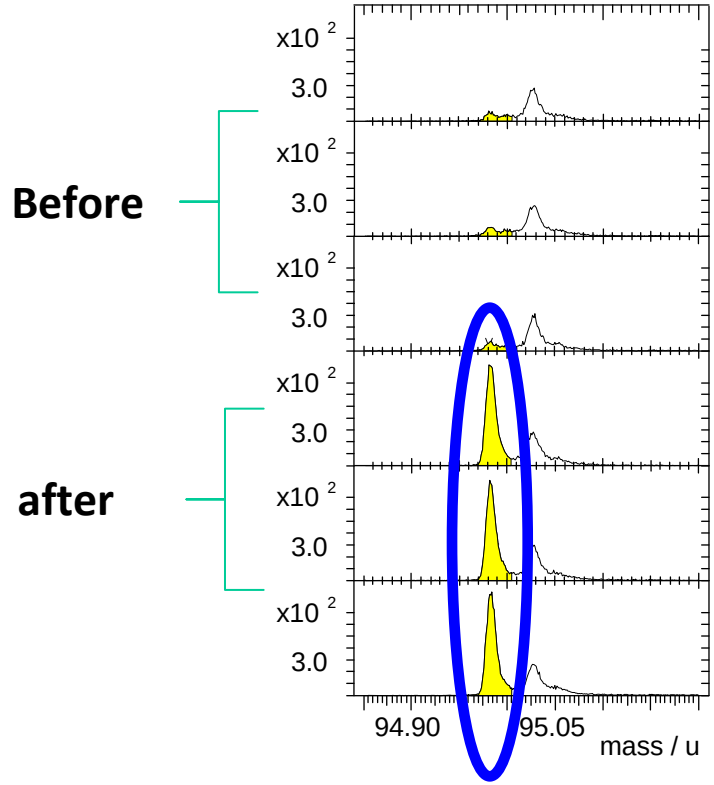
NTI UL③





Potential acid unit was decomposed after EUV exposure.

ION-TOF : TOF.SIMS5
Primary Ion : Bi3++ (0.2pA at 10kHz)
Area : 200 x 200 μm2



Acid peak was increased after EUV exposure.

Potential acid unit generated acid after EUV exposure.

Evaluation method of acid generation from UL

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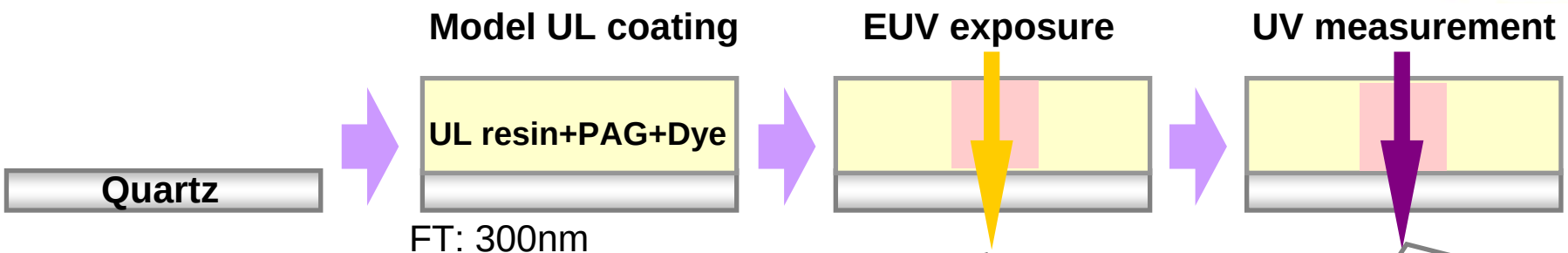
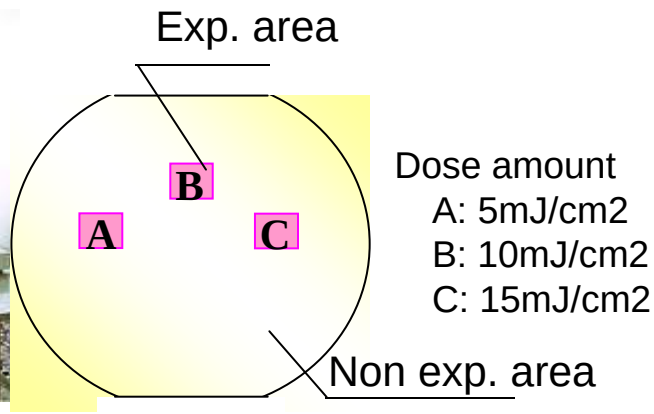
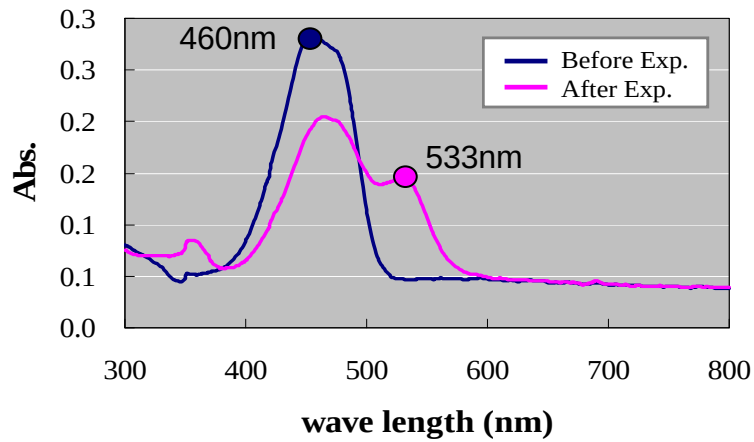


FT: 300nm
Bake : 100deg.C/60sec



Dose amount
A: 5mJ/cm2
B: 10mJ/cm2
C: 15mJ/cm2

EUV source (EQ-10M)

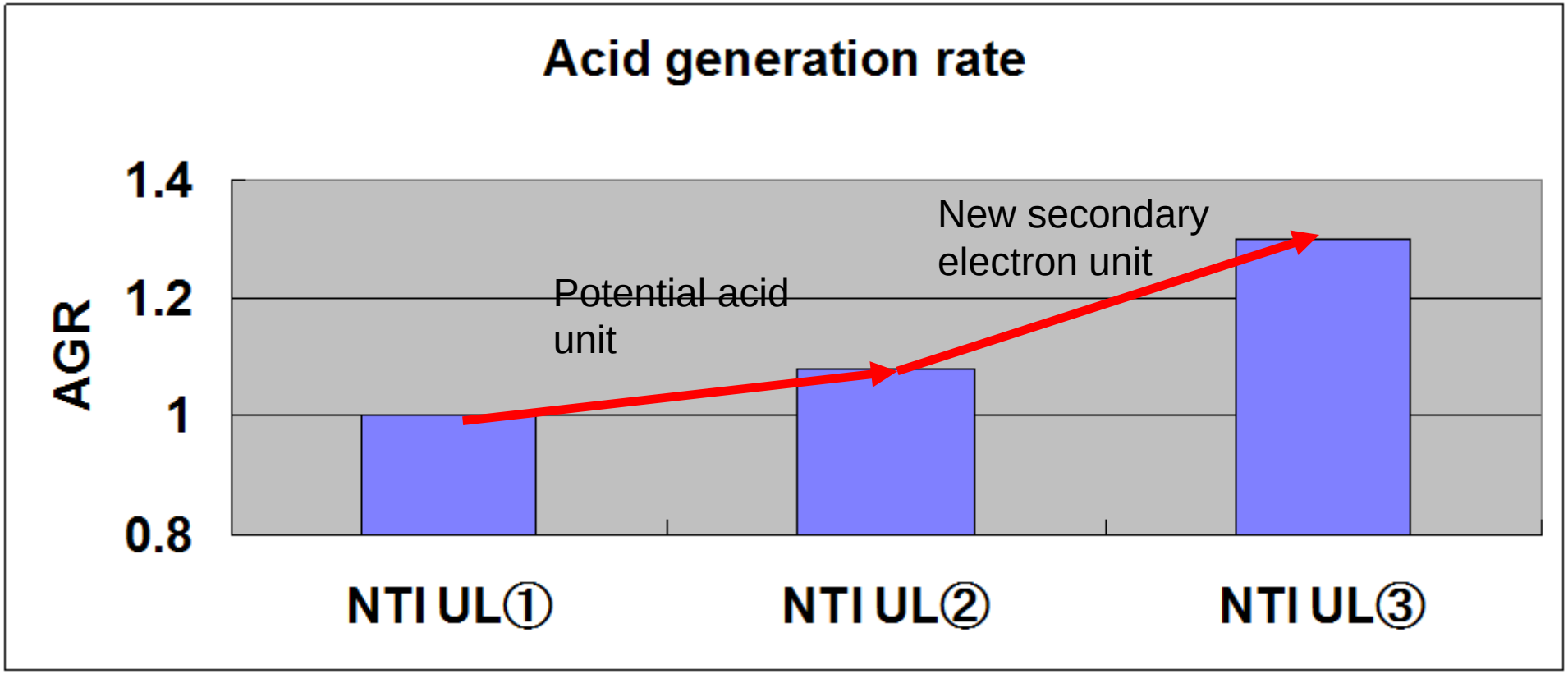


Absorption wavelength of Dye was changed by generated acid .
(460nm→533nm)

Acid generation amount was analyzed by changing of the absorption wavelength of Dye.

Acid generation amount result

NEXL™
Challenging and Solution by x-layer

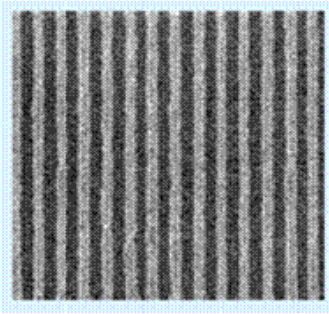
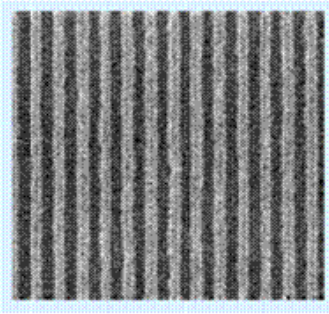
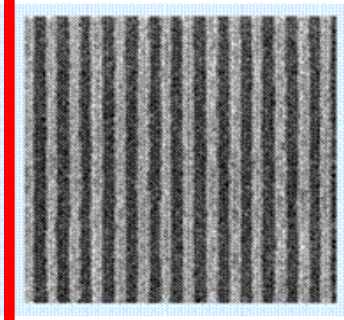


NTI UL③ resin generated acid more than NTI UL① and ②resin by potential acid unit and new secondary electron unit .

Comparison of the EUV lithography performance

NEXL™
Challenging and Solution by x-layer

UL: 5nm
PR: 50nm

Sample	NTI UL①	NTI UL②	NTI UL③
Top view hp25nm			
CD (nm)	24.4	25.8	24.4
Dose (mJ/cm^2)	18.0	18.0	18.0
LWR (nm)	4.2	3.7	3.5
Resolution limit	hp23nm	hp22nm	hp22nm

NTI UL③(W/ potential acid +high secondly electron unit) improved LWR dramatically compared with Ref..

Outline

- Introduction
- Developing status of ultra thin Org.UL
- Evaluation result of polymer additive and special additive UL (improving of LWR)
- Developing status of NTI UL (Next generation technology)
- **Summary**

Summary

- We developed ultra thin Org.UL (NCX1630) that was verified hp 17nm pattern.
- UL with PA-SCA improved adhesion and LWR. UL (W/PA-SCA) showed wide PW compared with Ref.UL (NCX1630) at hp22nm.
- UL (w/ special additive) improved LWR compared with Ref. .

- We developed NTI UL that achieved high adhesion and low LWR using two concepts. One is rigid structure resin and the other is acid assist system.
- NTI UL③(W/ potential acid +high secondly electron unit) showed high adhesion and improved LWR dramatically in NTI process.

- We developed ultra thin UL technology for both PTD and NTI EUV lithography at hp 1X generation.