EUVL Symposium 2016

October 24-26, 2016, Hiroshima, Japan

Nissan Chemical,
-where unique & solution meet

DDR Process and Materials for NTD Photo Resist toward 1Xnm Patterning and beyond

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Outline

About DDR process

About DDR process and material for NTD PR

Patterning data

- -Pattern reverse from L/S into L/S
- -Pattern reverse from pillar into C/H

Summary

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About DDR process and material for NTD PR

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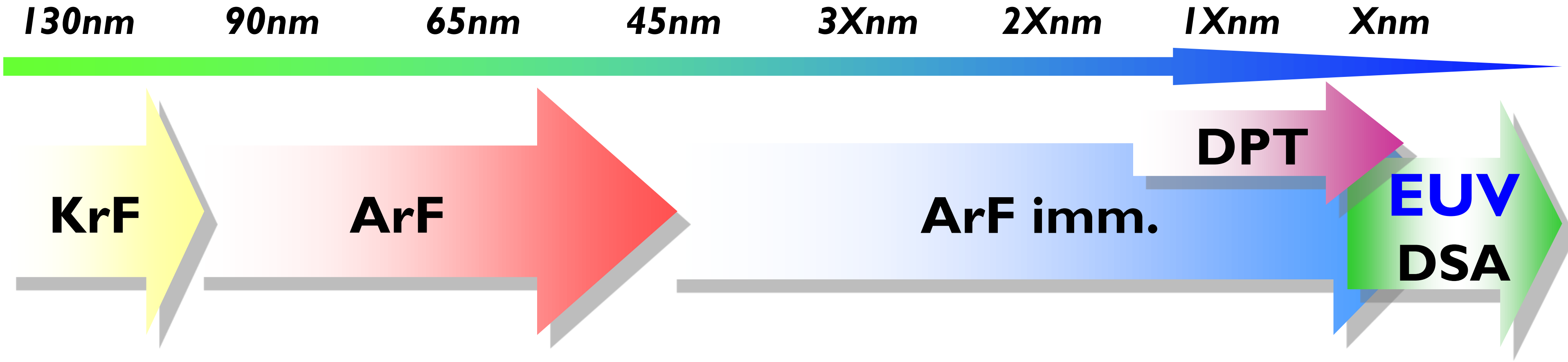
- -Pattern reverse from pillar into C/H

Summary

Lithography technique

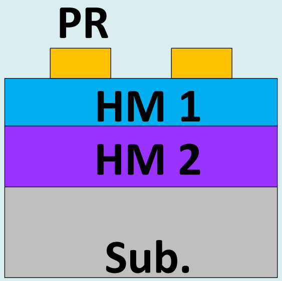
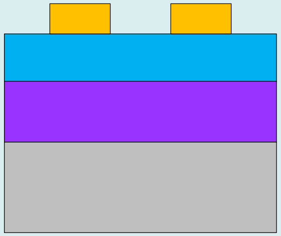
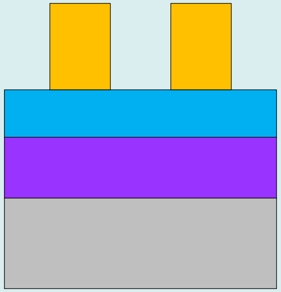
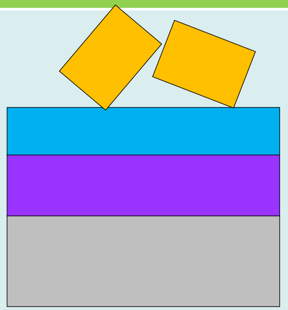
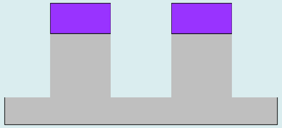
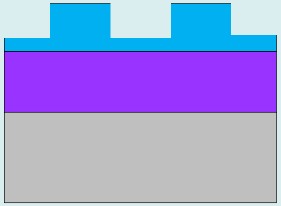
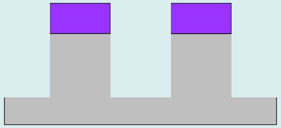
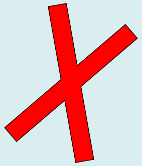
Lithography technique



Some lithography techniques have been demonstrated to create fine pattern.

EUV lithography is one of the candidate for next gen. lithography.

Difficulty in current process

Process step	**Thin PR**		**Thick PR**	
	Ideal	Actual	Ideal	Actual
Litho graphy				
Pattern transfer		Can't open HM… 		 Can't transfer…

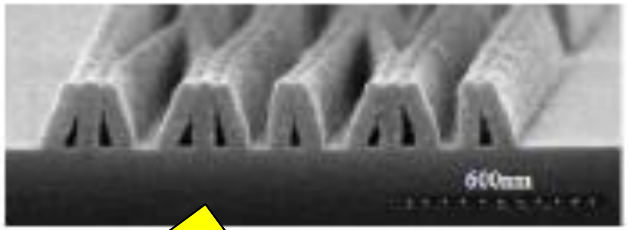
Thick PR is prefer to achieve pattern transfer.
⇒ Thicker PR cause pattern collapse…

Dry process is one of the solution to overcome this trade-off.

Dry process

sc CO2 Dry Development

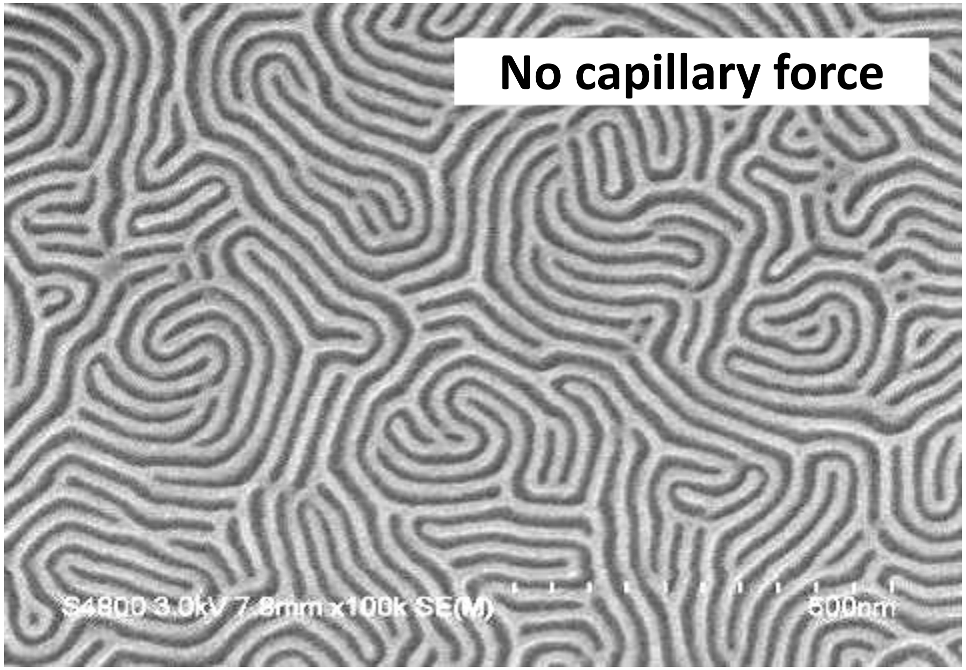
Wet Development



sc CO2

No capillary force

DSA (= Directed Self-Assembly)
【Pattern creation by Dry Etching】



No capillary force

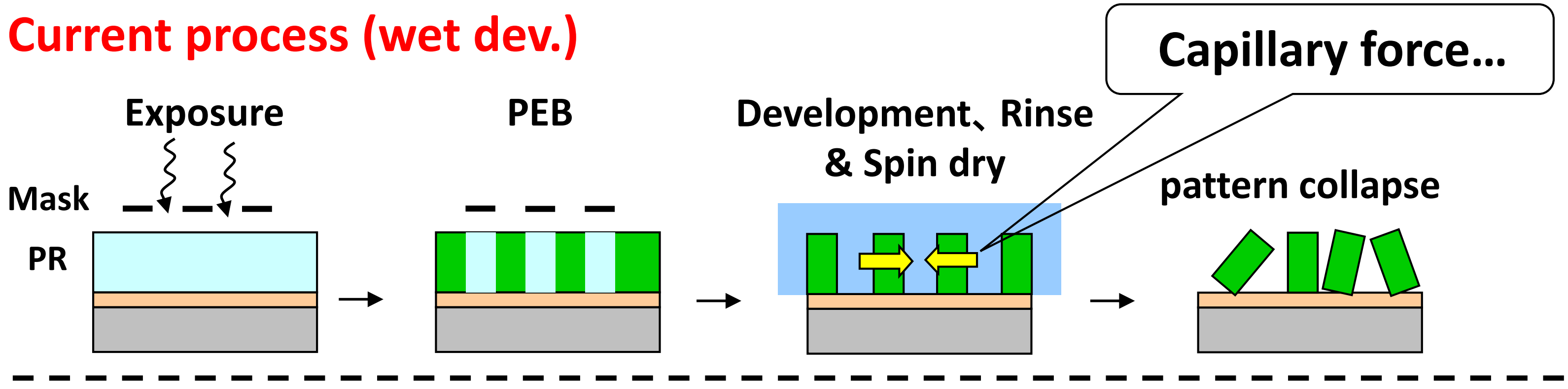
L0 = 30nm

Dry process can create fine pattern with high aspect ratio.

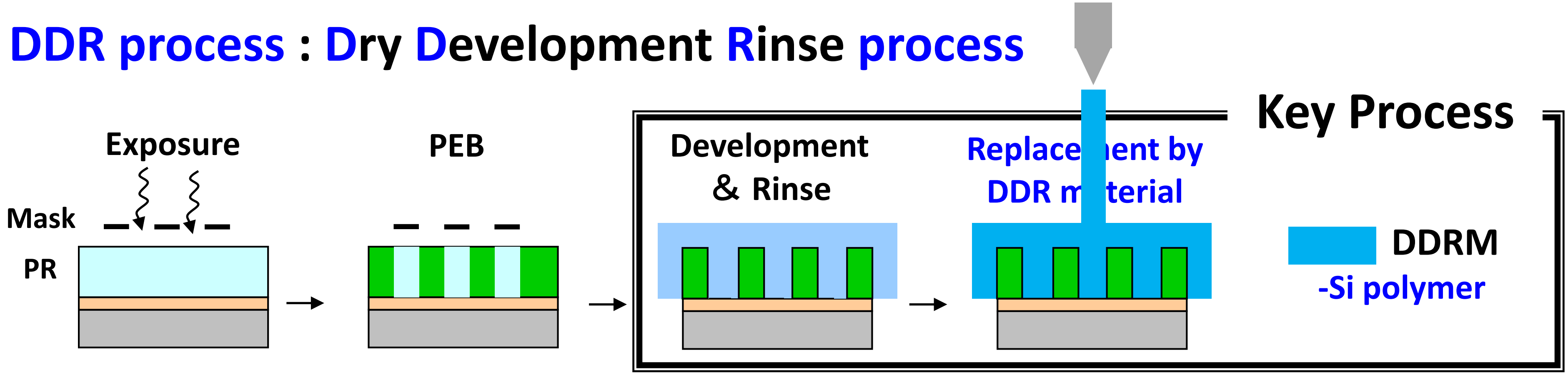
→ NissanChemical also has Dry process【DDR Process】

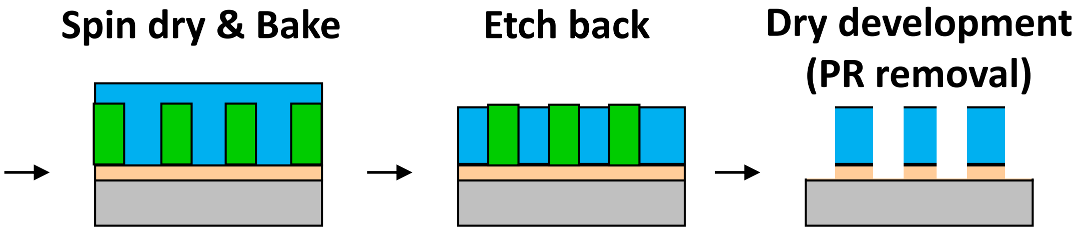
Dry Development Rinse process

Current process (wet dev.)



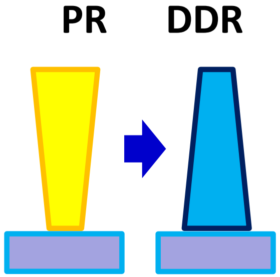
DDR process : Dry Development Rinse process





- Image reversal
- Collapse free process
- Easy pattern transfer
- Special tools unnecessary

Current progress for DDR process

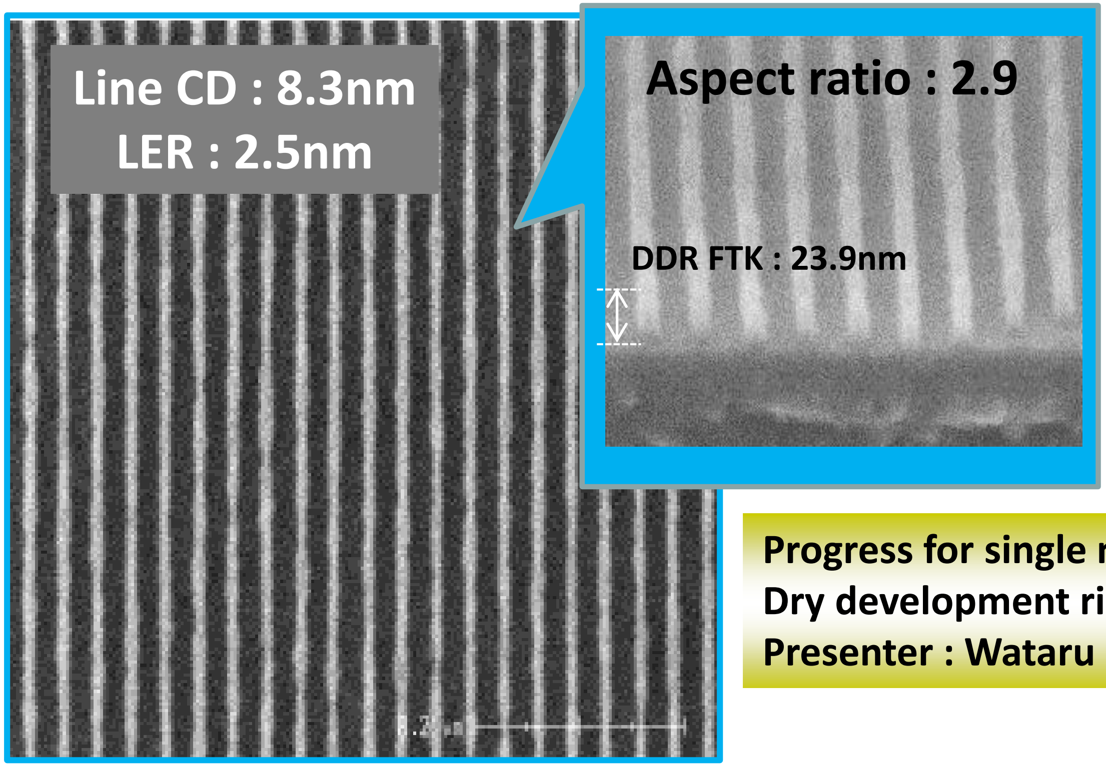


NCR500(80nm)

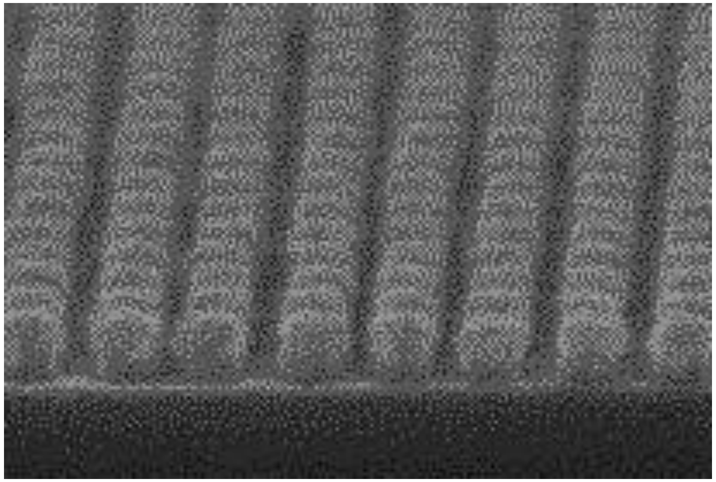
DDR specialized EUV PR (70nm)

Nissan Std. Si-HM

8nm Line (Pitch 32mn)



22hp Reversed pillar



Progress for single nm resolution by applying
Dry development rinse process (DDRP) and materials (DDRM)
Presenter : Wataru Shibayama (Poster)

How about NTD PR?

About DDR process

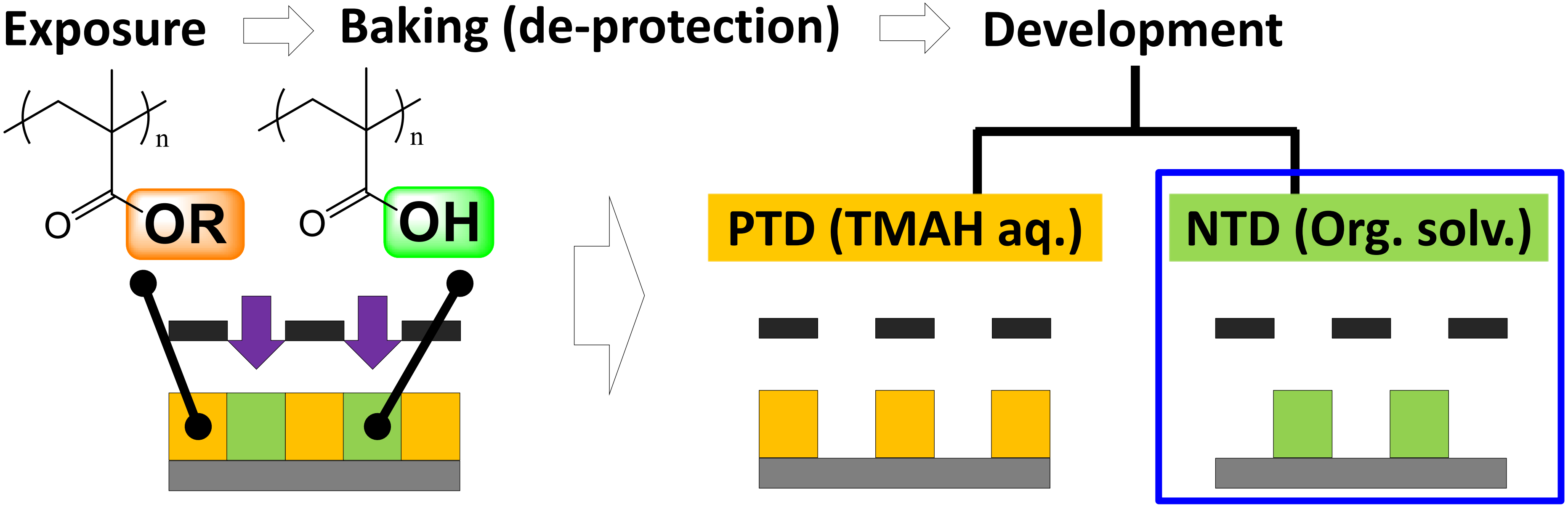
About DDR process and material for NTD PR

Patterning data

- -Pattern reverse from L/S into L/S
- -Pattern reverse from pillar into C/H

Summary

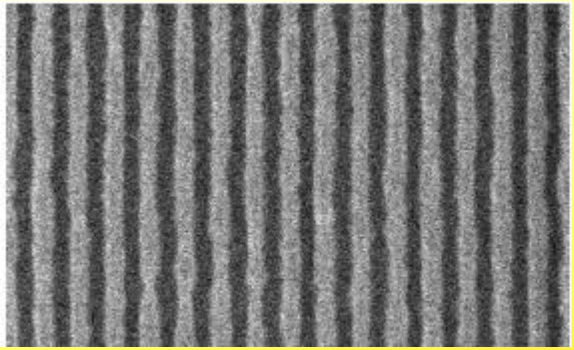
NTD process



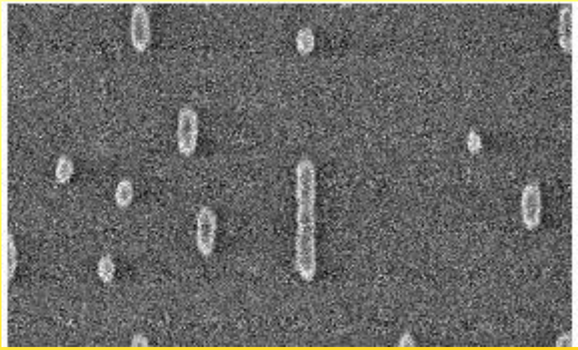
Exposure → Baking (de-protection) → Development

PTD (TMAH aq.)

NTD (Org. solv.)



EUV
14nm L/S$^{1)}$
37mJ/cm^2



EUV
21nm block$^{1)}$
18mJ/cm^2

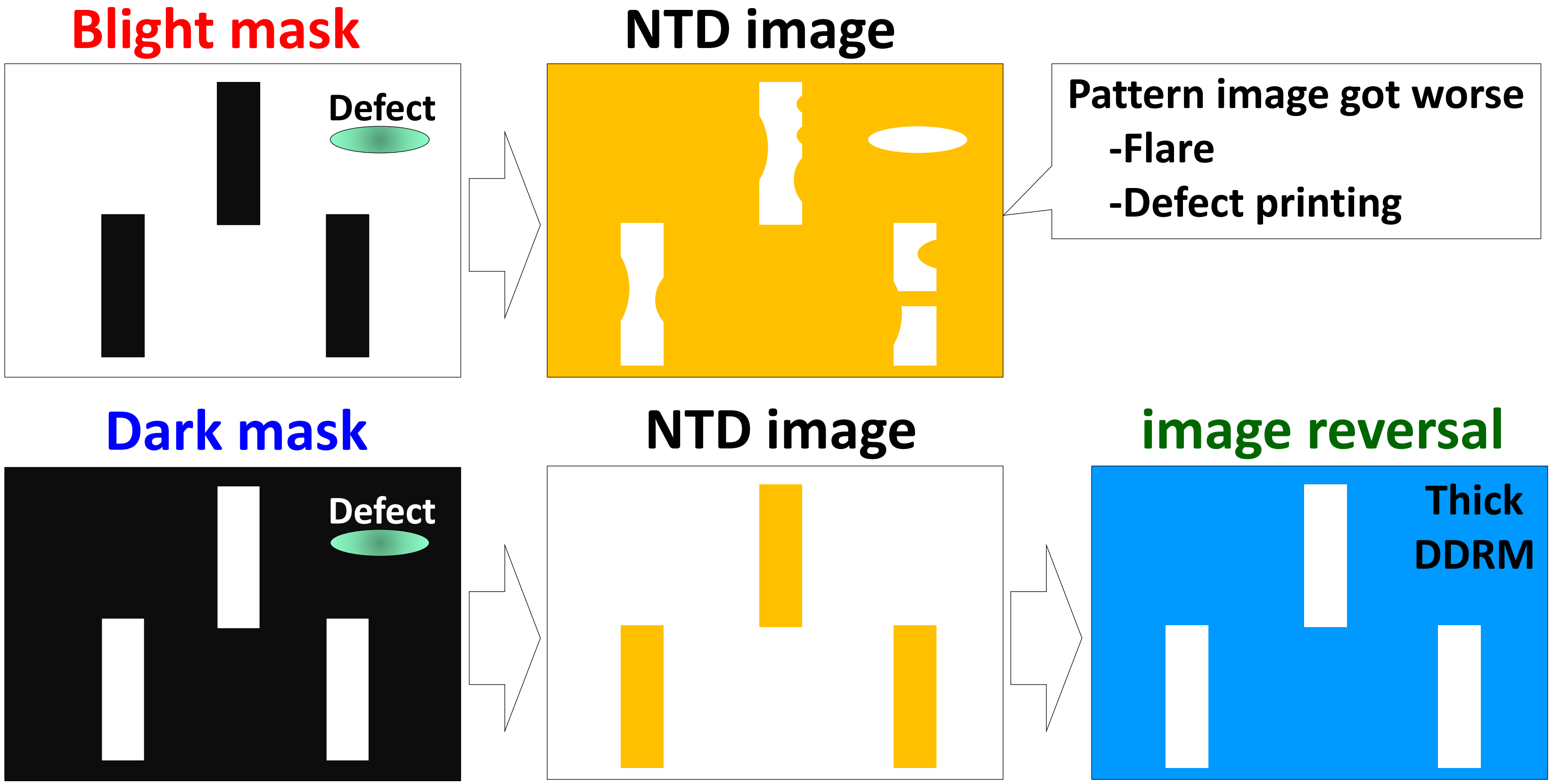
1) Proc. of SPIE, Negative-tone imaging with EUV exposure toward 13 nm hp, Fujifilm

Current NTD PR shows almost same performance compared to PTD-PR.

Merit of NTD-DDR process

In EUVL, dark field mask is the preferred because of defectivity, flare

Target : Fine Trench, C/H



NTD only

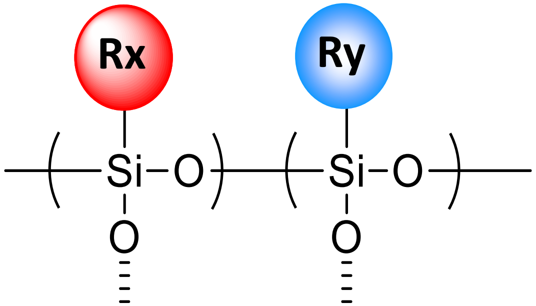
Pattern image got worse
-Flare
-Defect printing

NTD & Image reversal

C/H or trench can be created by NTD-DDR process with high quality.
It become easy to achieve pattern transfer due to using DDRM as HM.

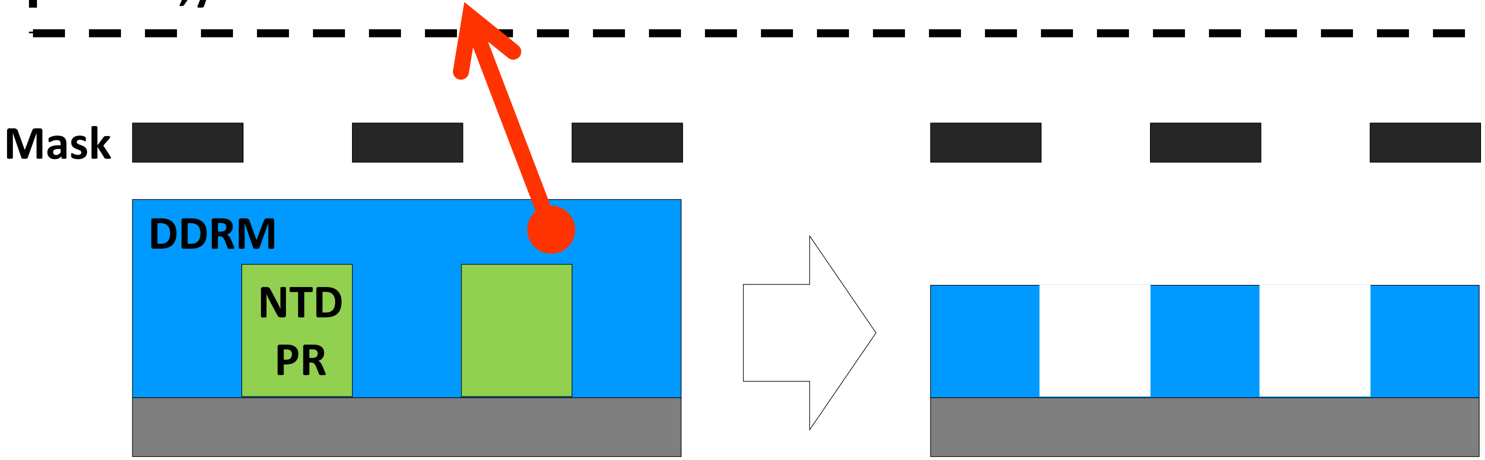
DDR Material for NTD PR

Dry Development Rinse Material : DDRM



Rx,y: Functional unit

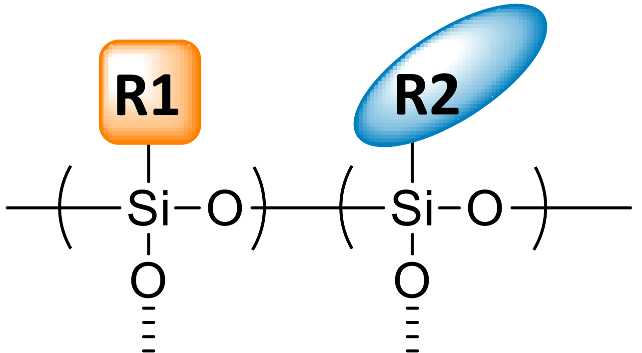
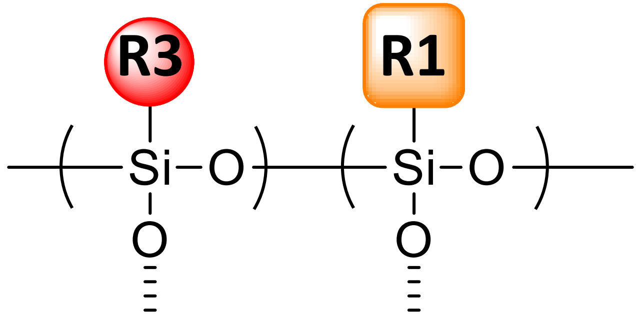
Solvent type	Etch Selectivity vs. PR	
	CF_4	O_2
Organic (For NTD)	1.1	< 0.05



Requirement:

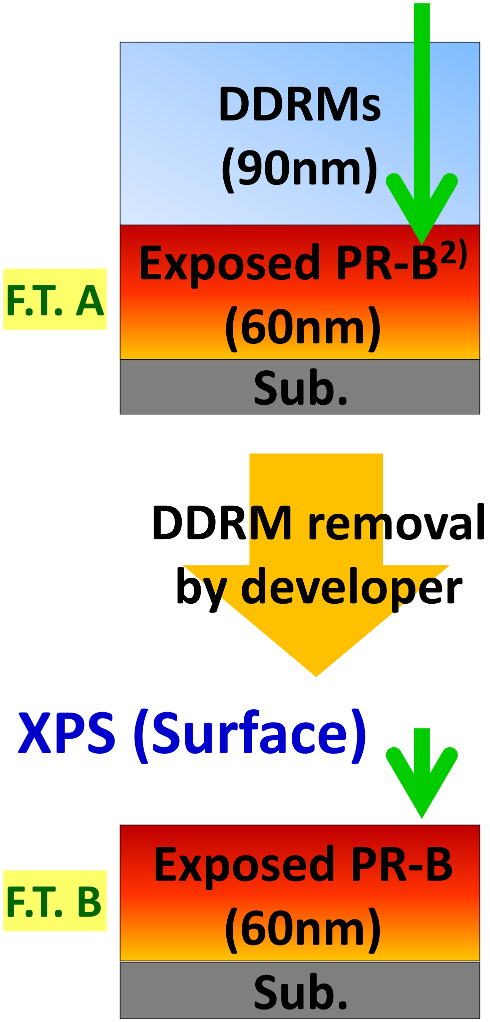
- ◆High compatibility for organic developer
- ◆Gap filling in narrow pitch
- ◆No mixing to NTD PR

Candidate of DDRM for NTD PR

Sample	NCR541	NCR581
Generation	2nd gen.	3rd gen.
Polymer		
Functional unit	R1,2 : Solubility for org. solv.	R1 : Solubility for org. solv. R3 : High cross-link density
Solvent	Org. solvent A	Org. solvent A
Si content (Normalized)	1.0	1.2

Study of mixing layer

ToF-SIMS (Depth direction)



F.T. A

DDRMs (90nm)

Exposed PR-B[2] (60nm)

Sub.

DDRM removal by developer

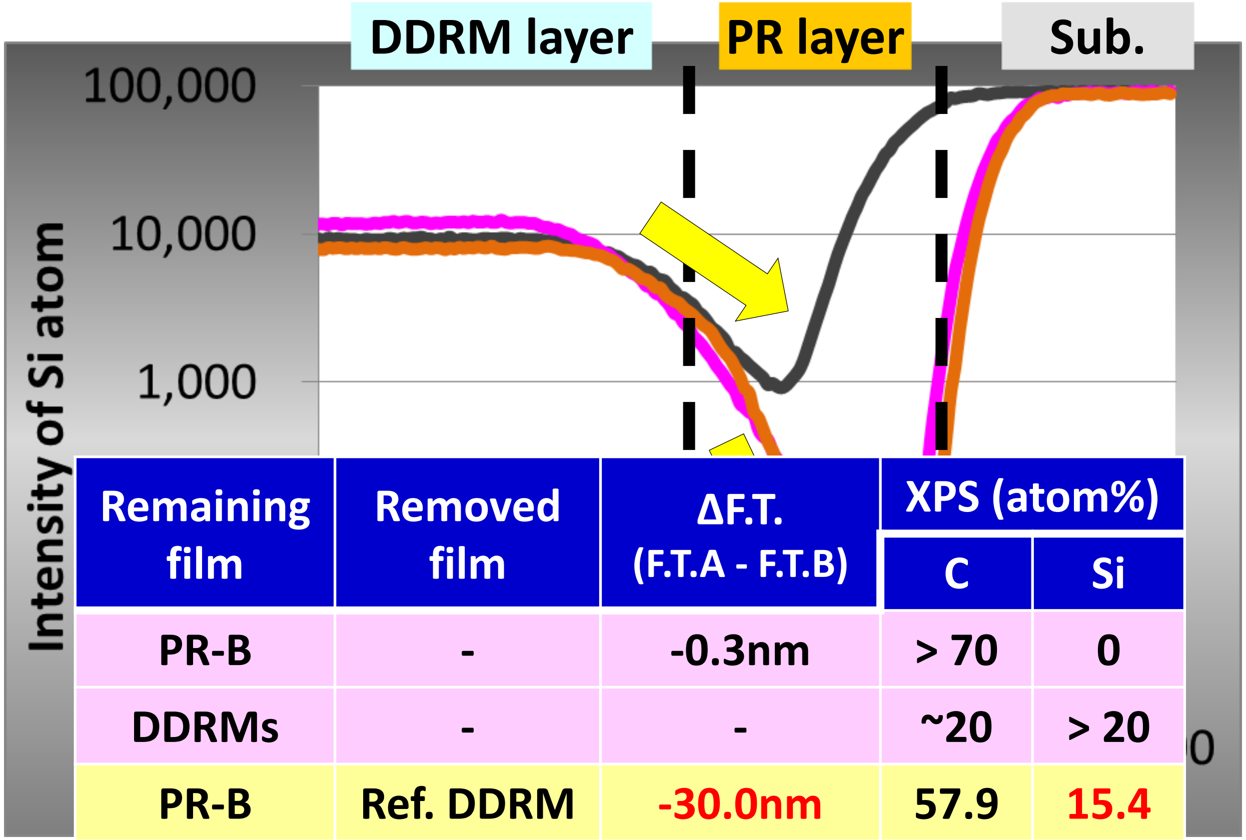
XPS (Surface)

F.T. B

Exposed PR-B (60nm)

Sub.

2) PR-B : imec STD, NTD-EUV PR



Remaining film	Removed film	ΔF.T. (F.T.A - F.T.B)	XPS (atom%)	
			C	Si
PR-B	-	-0.3nm	> 70	0
DDRMs	-	-	~20	> 20
PR-B	Ref. DDRM	-30.0nm	57.9	15.4
PR-B	NCR541	-1.2nm	72.6	1.3
PR-B	NCR581	-1.8nm	73.8	1.2

Mixing level : Low

About DDR process

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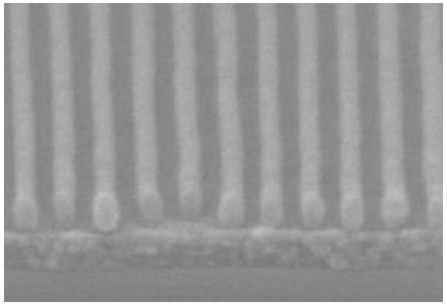
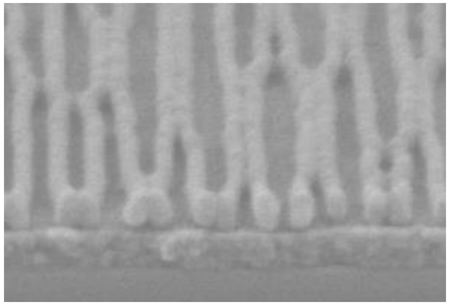
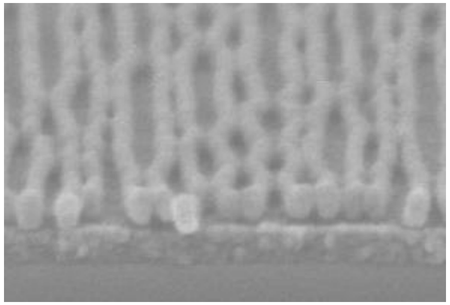
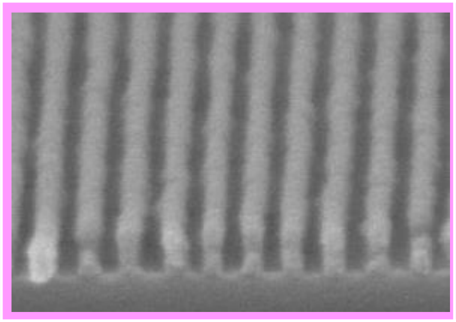
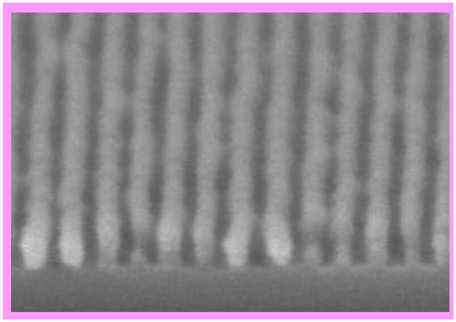
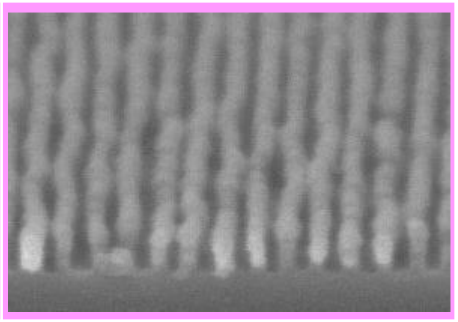
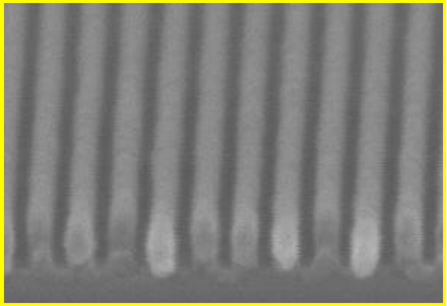
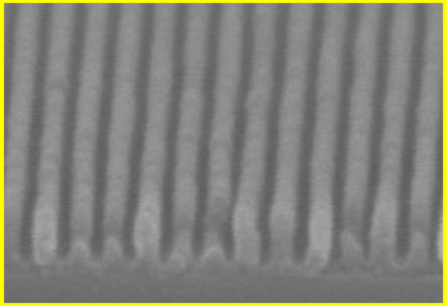
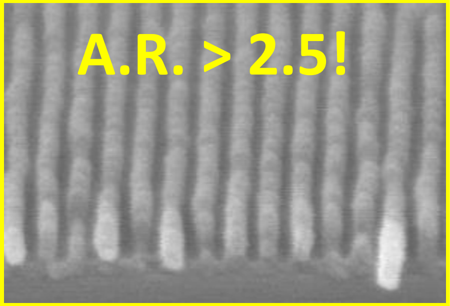
- -Pattern reverse from L/S into L/S
- -Pattern reverse from pillar into C/H

Summary

Patterning @hp14~18nm

NXE3300 (imec), NA: 0.33

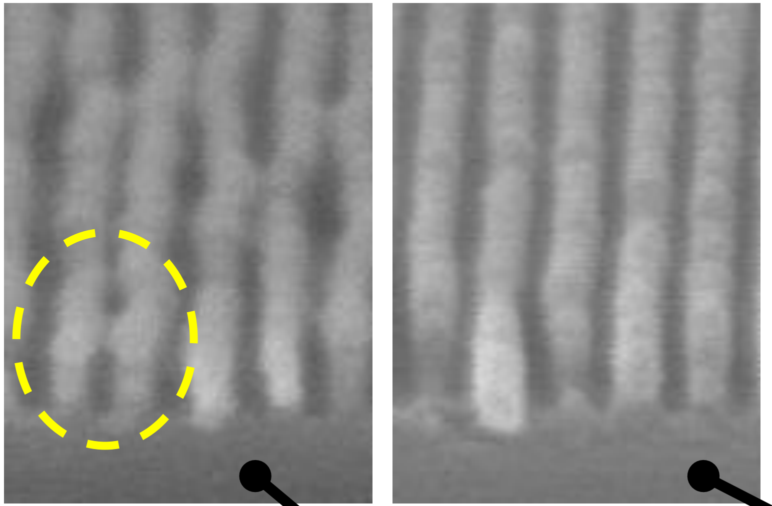
	hp18nm	hp15nm	hp14nm
Normal NTD (w/o rinse) **PR-B (Fujifilm, 40nm)**			
NCR541 **Previous DDRM**			
NCR581 **High cross-link type**			 A.R. > 2.5!

High cross link type DDRM showed good patterning property.

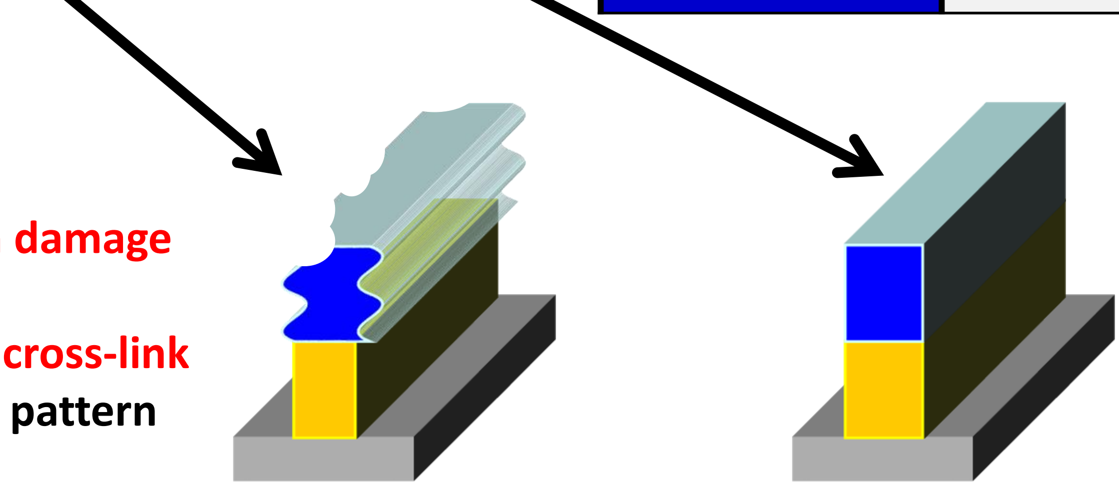
Pattern wigging after etching

NCR541
hp 14nm

NCR581
hp 14nm



Property	NCR541	NCR581
Mixing level	1.0 – 1.5nm	
Si content (Normalized)	1.0	1.2
Film density (Normalized)	1.0	1.1
O_2 Etch rate (Normalized)	1.0	< 0.5



Etch damage

low cross-link
Soft pattern

Low etch damage

High cross-link
Rigid pattern

About DDR process

About DDR process and material for NTD PR

Patterning data

- -Pattern reverse from L/S into L/S
- -Pattern reverse from pillar into C/H

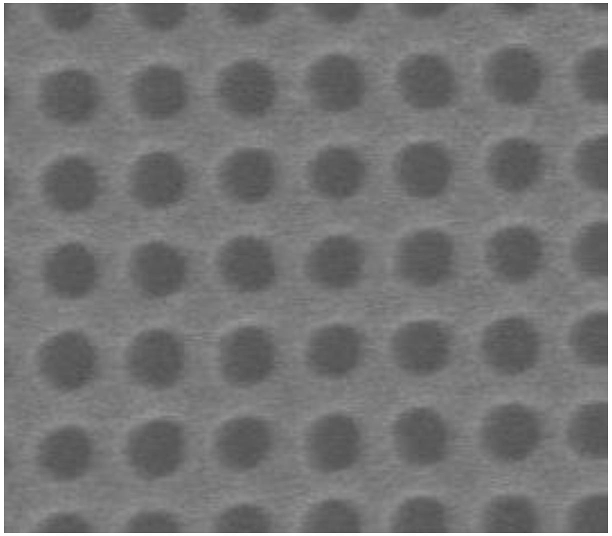
Summary

Comparison of LCDU

CD size 30nm / Pitch 52nm, PR-B, F.T. : 40nm

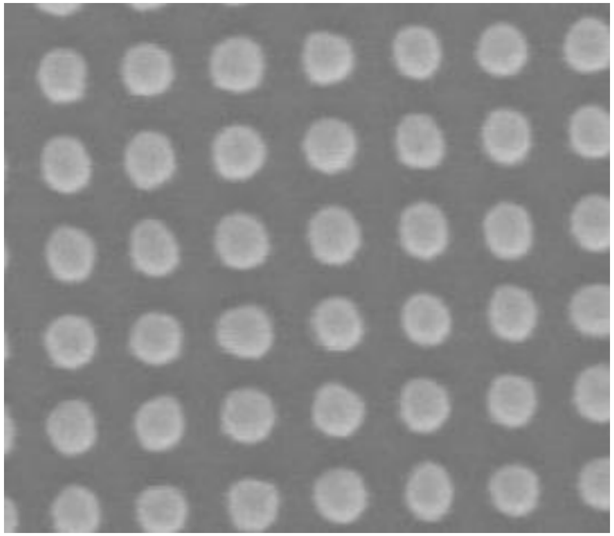
NXE3300 (imec), NA: 0.33

PTD C/H
(imec STD)



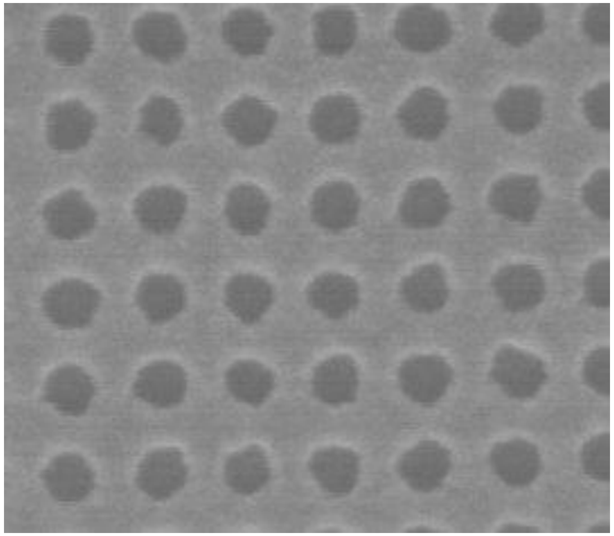
Ave. CD: 32.2nm
Range: 1.6nm
3σ: 1.5nm

NTD Pillar
(PR-B, imec STD)



Ave. CD: 32.1nm
Range: 1.9nm
3σ: 0.8nm

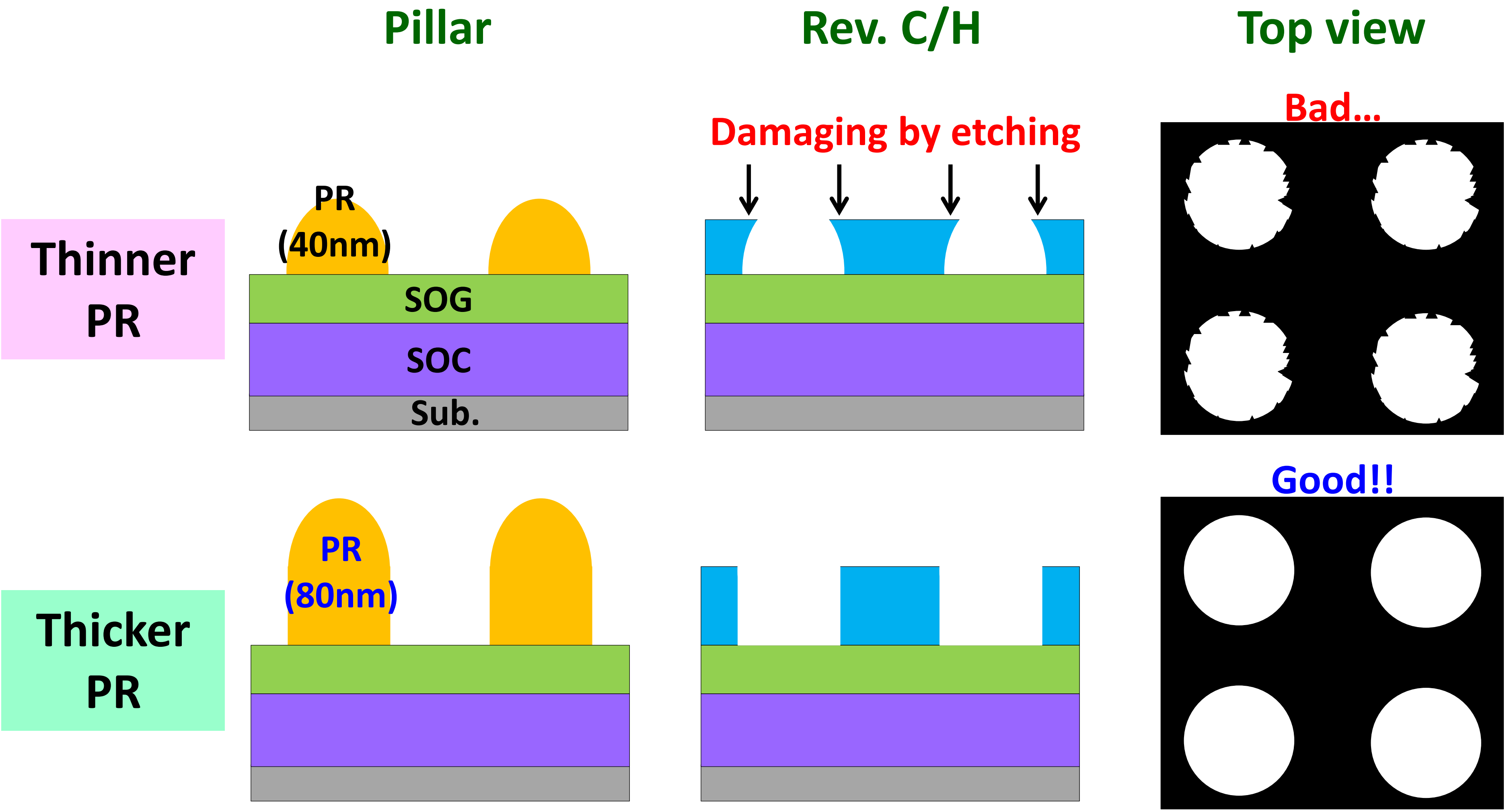
NTD Pillar
→ C/H (NCR581)



Ave. CD: 28.7nm
Range: 1.9nm
3σ: 1.5nm

Rev. C/H of DDRM showed same LCDU compared to PTD C/H in EUVL. There were still gap compared to original pillar.

Dependence of pattern shape

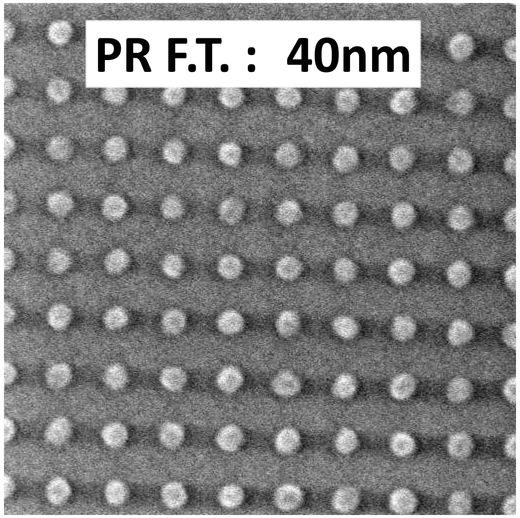


To use thicker PR and to apply enough etch back are useful for good LCDU.

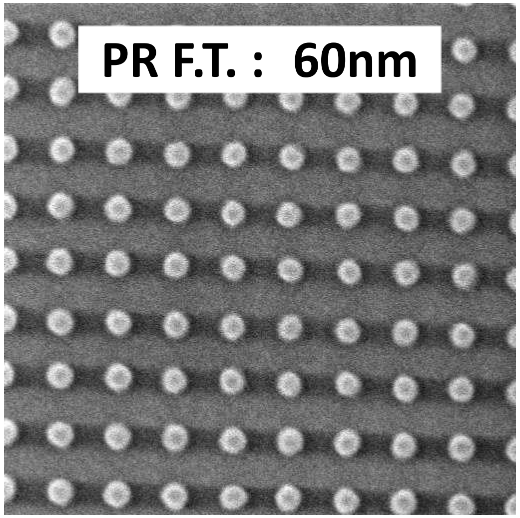
Dependence of PR thickness

Pillar 30nm / Pitch 60nm, PR-B, F.T. : 40~80nm

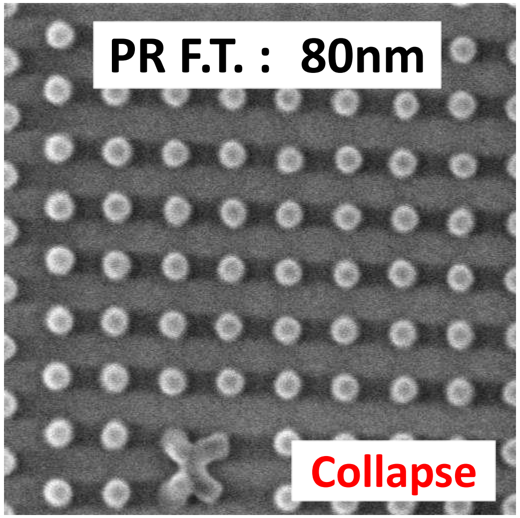
EB tool (Elionix), 130kV, 50pA



Ave. CD: 25.7nm
Max CD: 26.5nm
Min CD: 24.9nm
Range: 1.6nm
3σ: 1.1nm



Ave. CD: 27.4 nm
Max CD: 27.9nm
Min CD: 26.9nm
Range: 1.0nm
3σ: 0.8nm



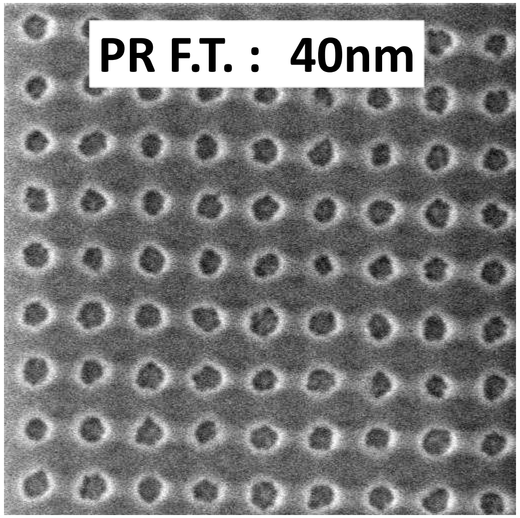
Ave. CD: (29.7nm)
Max CD: (30.3nm)
Min CD: (29.2nm)
Range: (1.1nm)
3σ: (0.8nm)

Thicker PR tended to be better LCDU.
Pillar pattern was collapsed when match thicker PR was used.

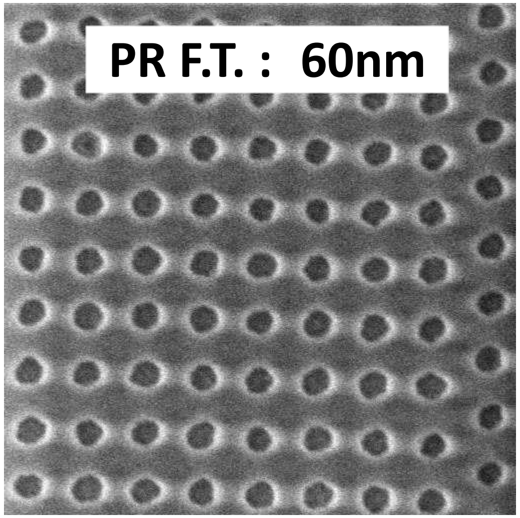
Dependence of PR thickness

Hole 30nm / Pitch 60nm, PR-B, F.T. : 40~80nm

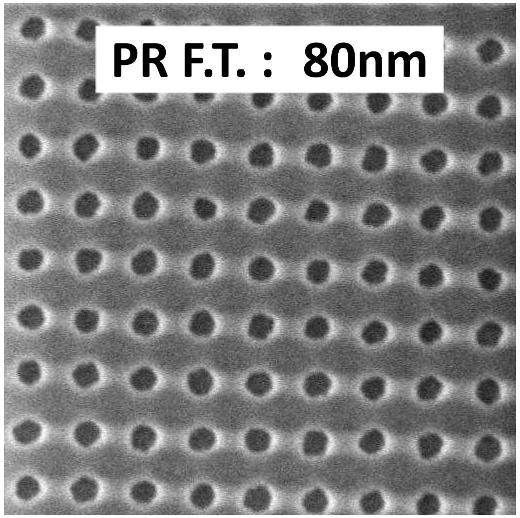
EB tool (Elionix), 130kV, 50pA



Ave. CD: 25.5 nm
Max CD: 26.8nm
Min CD: 22.2nm
Range: 4.6nm
3σ: 1.5nm



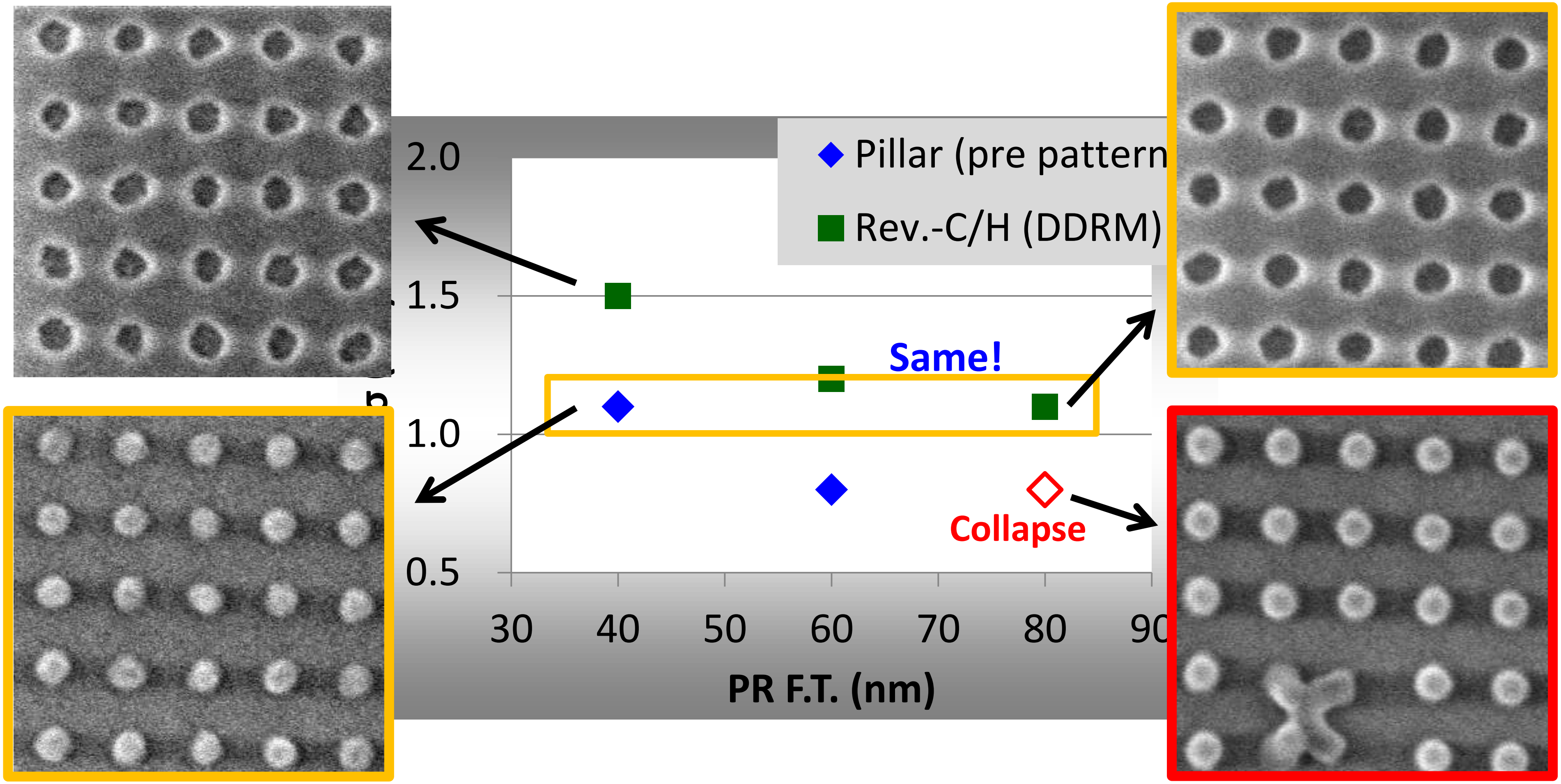
Ave. CD: 28.7 nm
Max CD: 30.2nm
Min CD: 27.2nm
Range: 3.0nm
3σ: 1.2nm



Ave. CD: 28.2 nm
Max CD: 29.5nm
Min CD: 27.0nm
Range: 2.5nm
3σ: 1.1nm

LCDU became better when thicker pre-pattern was reversed.

Summary of LCDU study



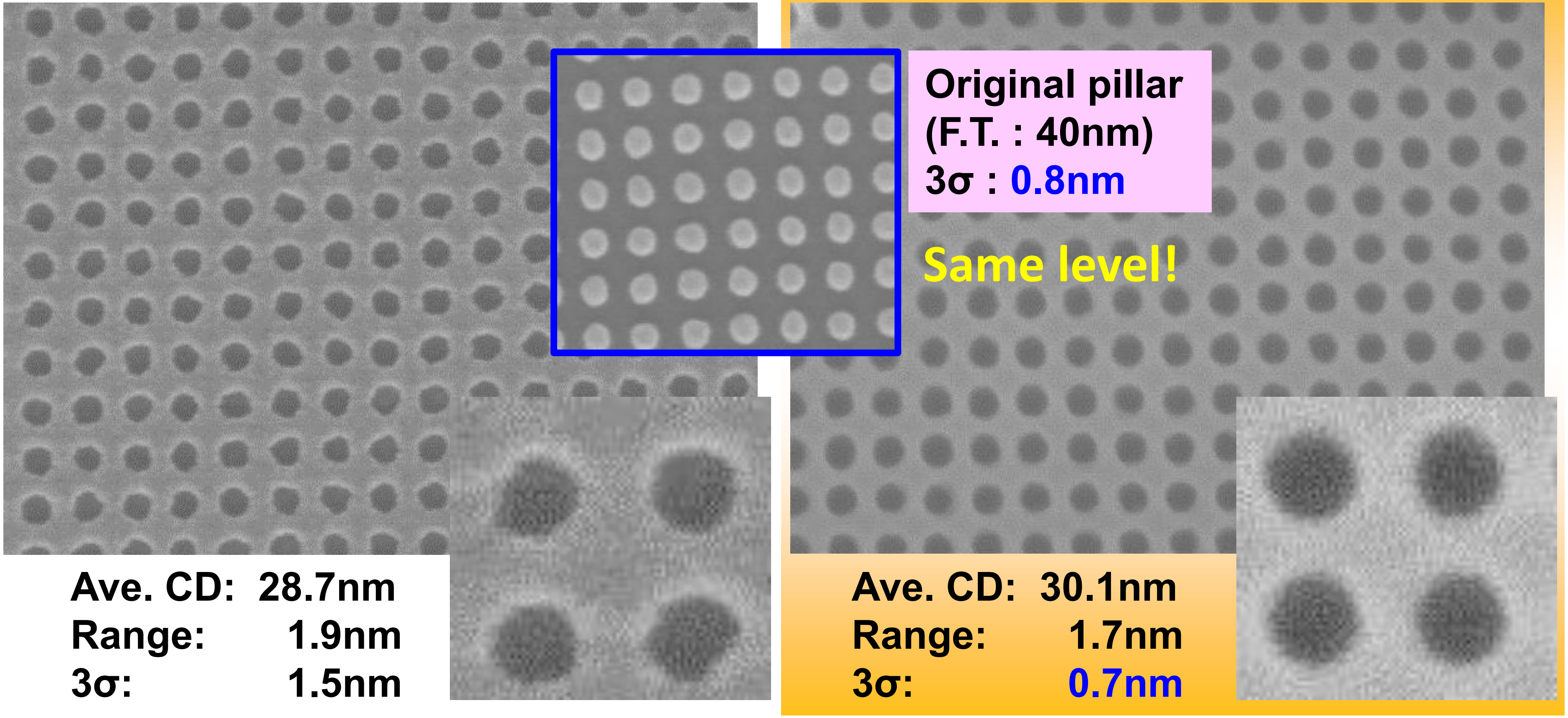
In DDR process, LCDU could be improved by using match thicker PR.

C/H creation with thicker PR

NXE3300 (imec), NA: 0.33

Rev. C/H (PR F.T. : 40nm)

Rev. C/H (PR F.T. : 80nm)



Original pillar
(F.T. : 40nm)
3σ : 0.8nm

Same level!

Rev. C/H (PR F.T. : 40nm):

Ave. CD:	28.7nm
Range:	1.9nm
3σ:	1.5nm

Rev. C/H (PR F.T. : 80nm):

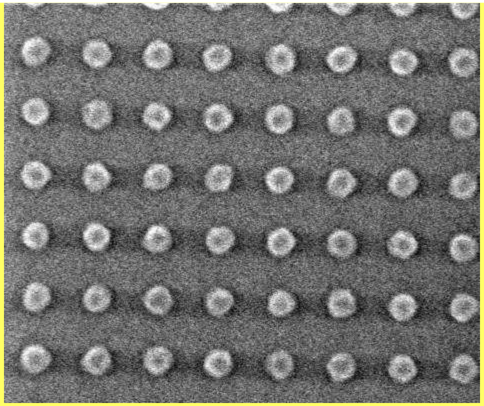
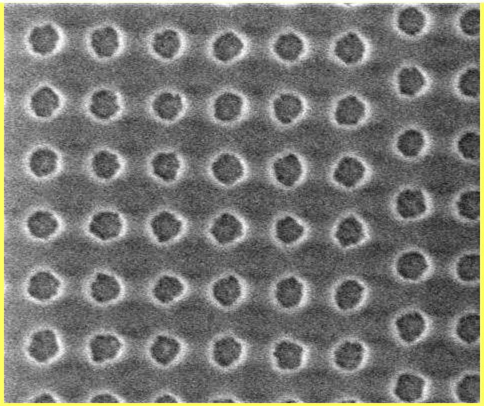
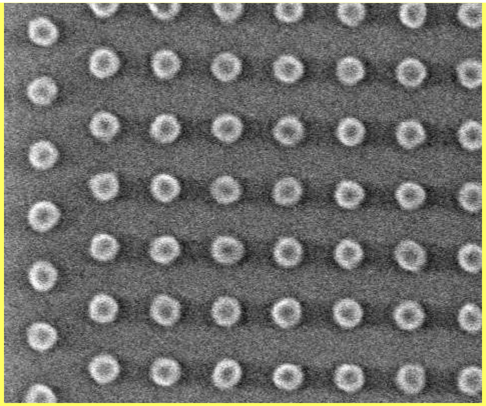
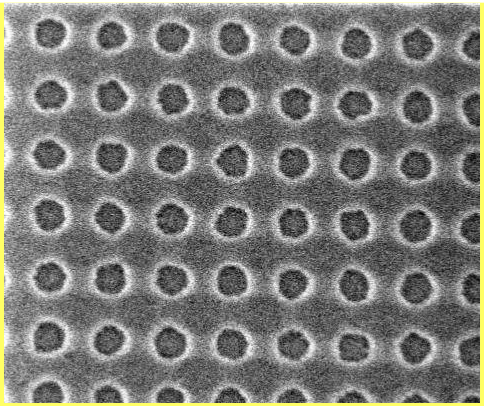
Ave. CD:	30.1nm
Range:	1.7nm
3σ:	0.7nm

CDU of Rev. C/H can be improved by using thicker PR.

C/H creation by high sensitive PR

CD size 40nm / Pitch 80nm

EB tool (Elionix), 130kV, 50pA

PR series	Pillar (NTD)		Rev. C/H (NTD-DDR)	
PR-B Fujifilm Imec STD F.T. : 40nm		Dose: 380uC/cm^2 Ave. CD: 35.9 nm 3σ: 1.5nm		Dose: 380uC/cm^2 Ave. CD: 35.1 nm 3σ: 2.3nm
PR-C Fujifilm High sensitivity F.T. : 40nm		Dose: 200uC/cm^2 Ave. CD: 37.7 nm 3σ: 1.4nm		Dose: 200uC/cm^2 Ave. CD: 38.7 nm 3σ: 2.0nm

DDR process showed potential to create fine C/H with high sensitivity.

Summary

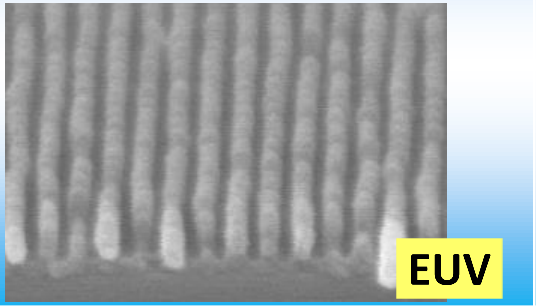
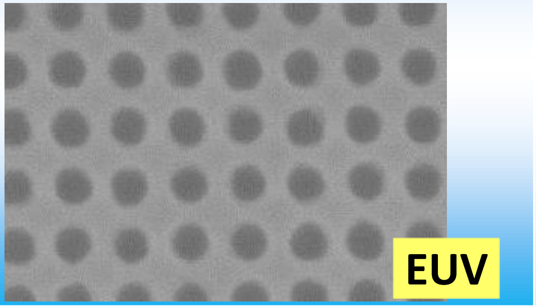
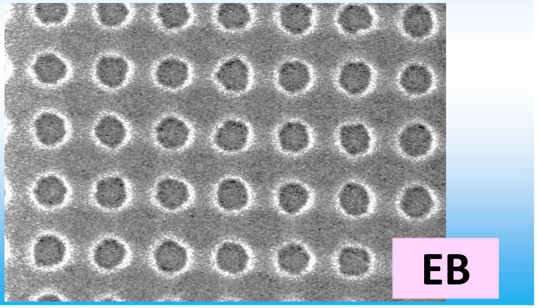
New DDRM showed low damage property against NTD PR by ToF-SIMS & XPS analysis.

New DDRM with high Si content and high density showed good patterning property in EUV lithography.

Pattern reverse from pillar into C/H was successfully achieved with good LCDU in NTD-DDR process.

LCDU of reversed C/H was improved when thicker PR was applied.

NTD-DDR showed the potential to make fine C/H at match lower dose.

Resolution	LWR (CDU)	Sensitivity
HP14nm, A.R. > 2.5!	**C30P60, 3σ : 0.7nm!** **(Same level of original PR)**	**C40P80** **Twice times high sensitivity!** **compared to STD PR**
		

Acknowledgement

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Thank you for your kind attention.