Dry Development Rinse (DDR) Process and Material for New Collapse Free Technique toward 1X nm hp and Beyond

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Outline

- Introduction
- About DDR process and materials
- Improvement of resolution by DDR process
- Roughness study with DDR process
- Candidates of DDR materials
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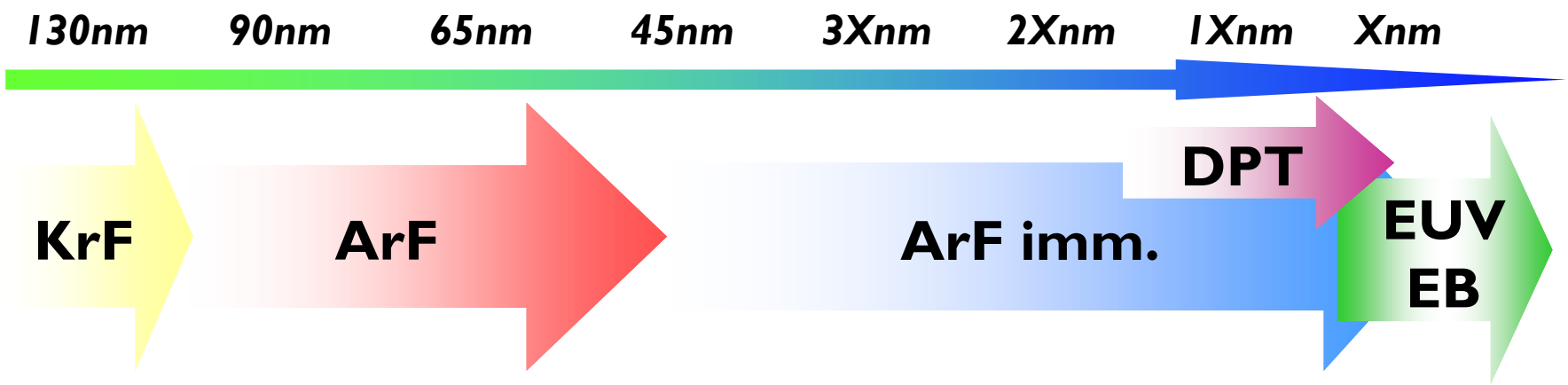
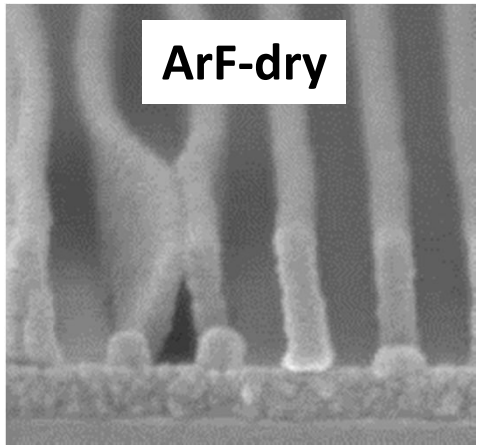
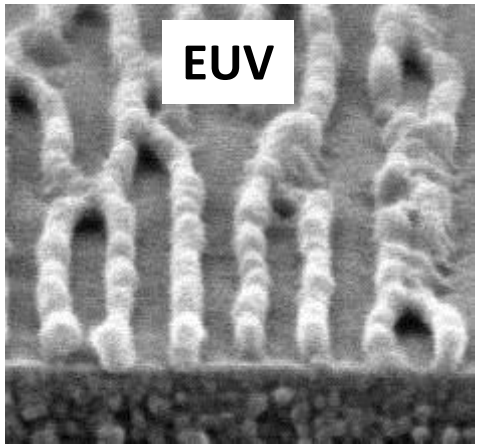
Introduction

Lithography technique

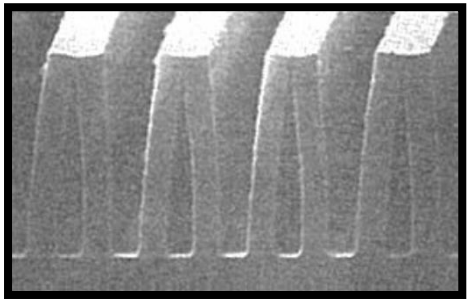




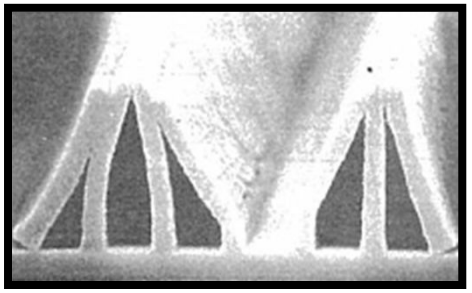


Pattern collapse is common issue in all generations and it became more severe in 1X nm hp and beyond.

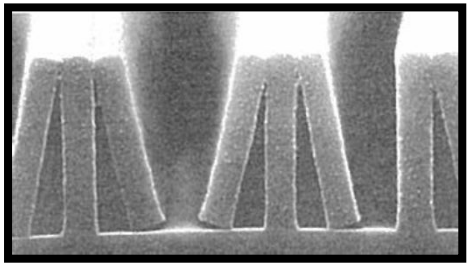
Root cause of the pattern collapse



Bending



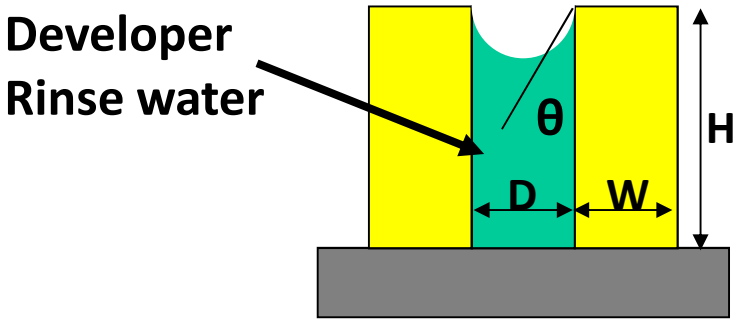
Breaking



Peeling

Root cause

Capillary force



$$\sigma_{max}=6\gamma A^2/D\cdot\cos\theta$$

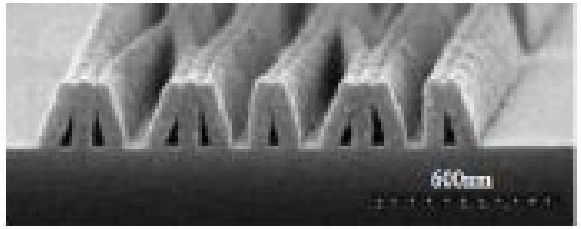
σ_{max} :Max. stress to resist
γ :Surface tension
A :Aspect ratio H/W
D :Space width
θ :Contact angle

If capillary force doesn't work, pattern collapse can't occur.

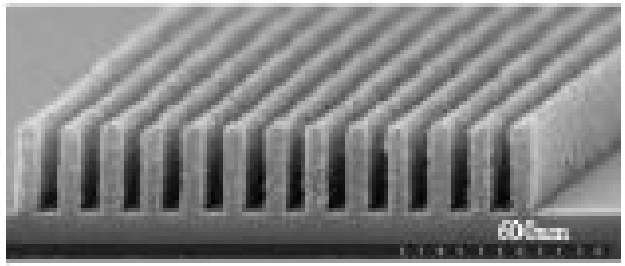
Prevention of collapse by dry development

sc CO2 Dry Development

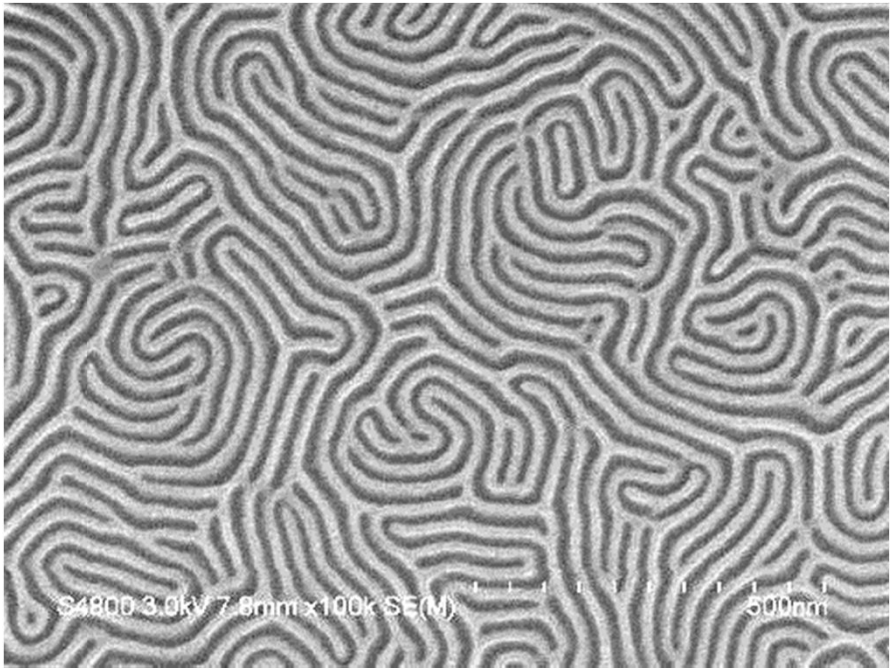
Wet Development



sc CO2



DSA
【Pattern creation by Dry Etching】



L0 = 30nm

Dry Development process is candidate for next generation patterning.
Capillary force doesn't work in Dry Development.

⇒Introduce "DDR process" which prevents capillary force.

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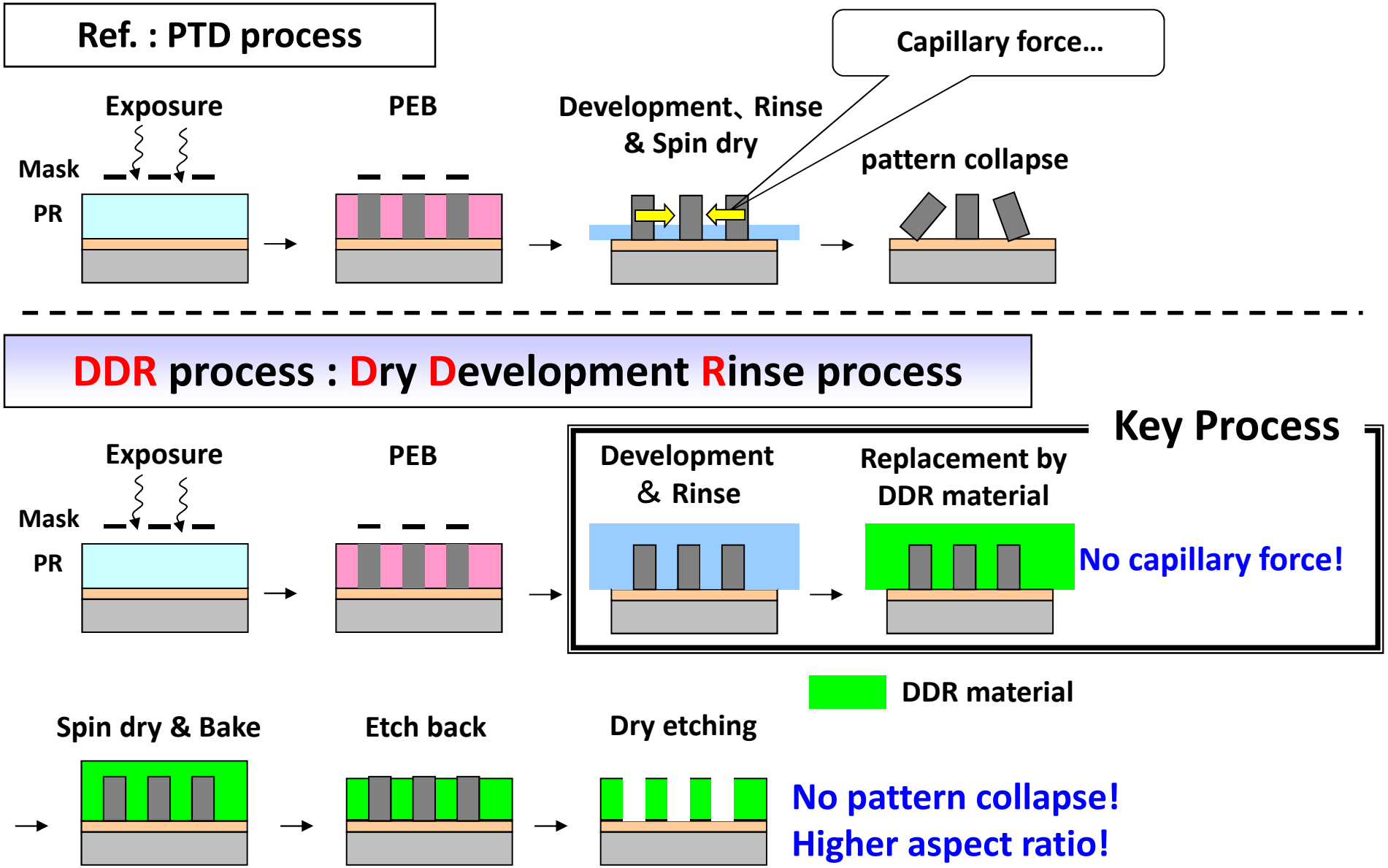
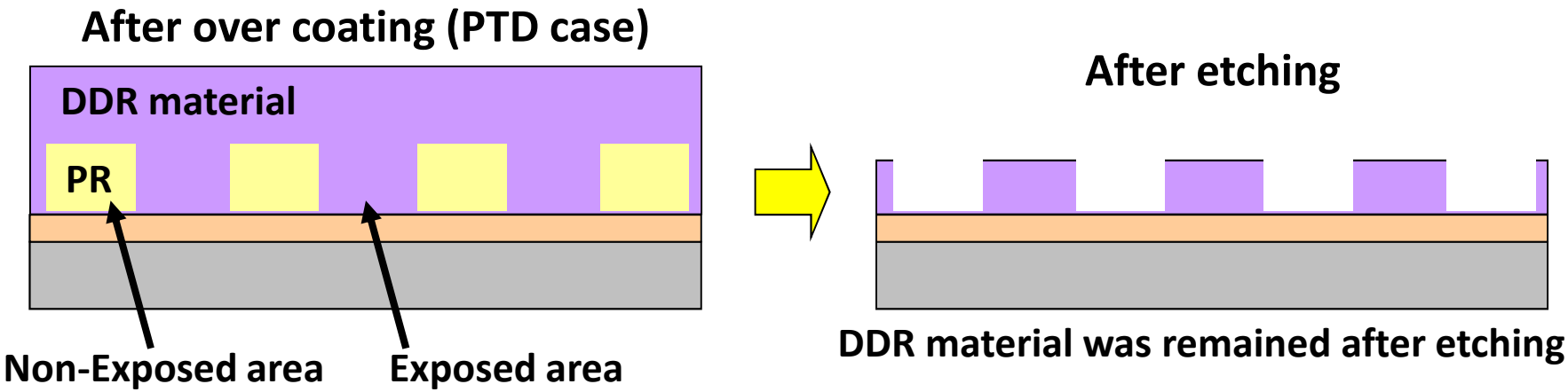
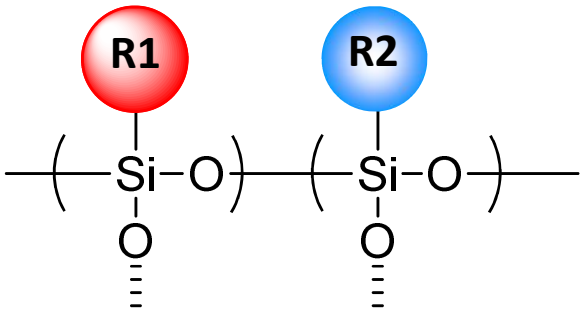
About DDR process



About DDR materials

DDR material: Dry Development Rinse material (Polymer + Solvent + add.)





R1,2: Functional unit

Solvent type	Etch Selectivity vs. PR	
	CF_4	O_2
Water (For PTD)	1.3 - 1.6	<0.1
Organic (For NTD)		

- Space area are filled by DDR material, reverse pattern are obtained.
- DDR material has higher etching selectivity against PR.

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Improvement of the resolution

Demonstration by EUV

Exposure condition;
NXE:3100

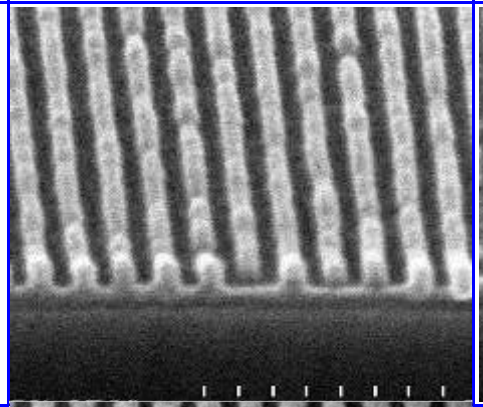
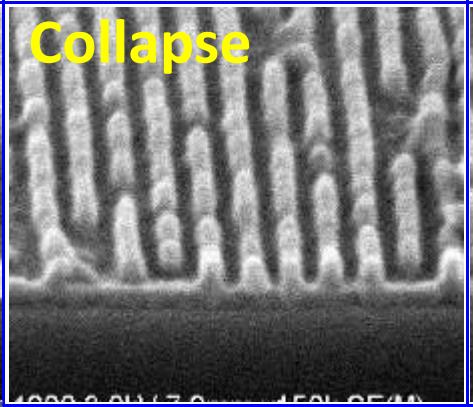
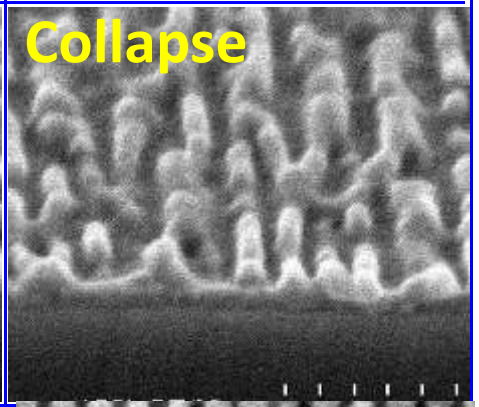
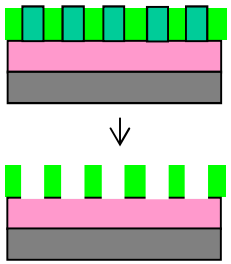
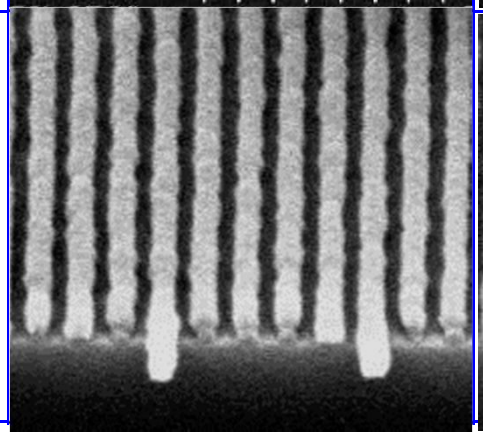
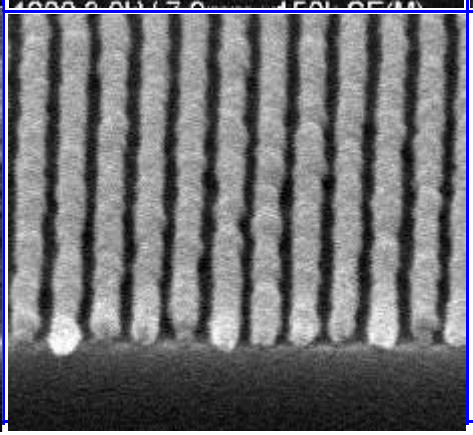
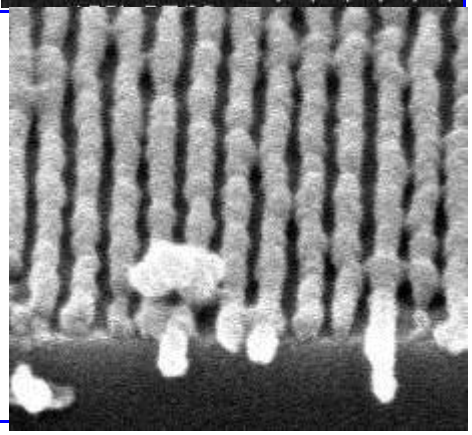
Stack;
NCR21 (40nm) /
PR-A (40nm) / UL (20nm)

Target CD;
17-19nm L/S

Development and Rinse;
CLEAN TRACK LITHIUS Pro Z (TEL)

Improvement of the resolution

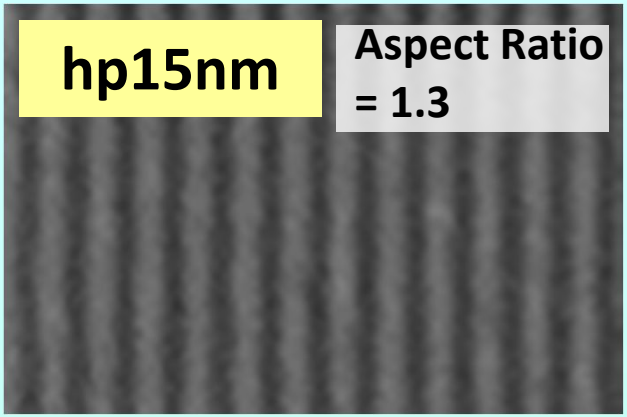
Mask: hp17-19nm, PR-A: 40nm FTK

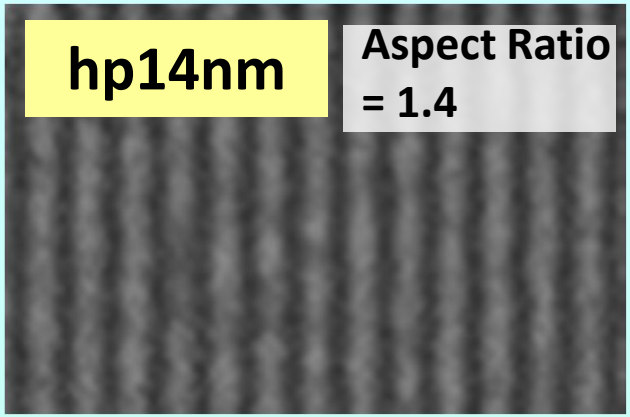
	hp19nm	hp18nm	hp17nm
PTD (Ref.)			
DDR 			

Pattern collapse was dramatically improved by using DDR process!

Improvement of the resolution

PR Pattern: PR-B (20nm) EUV exp.

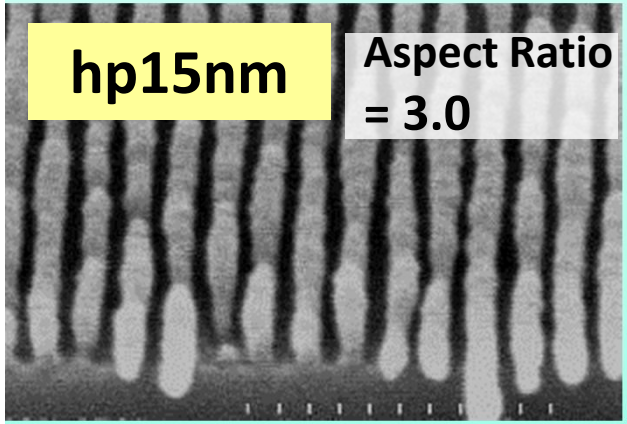


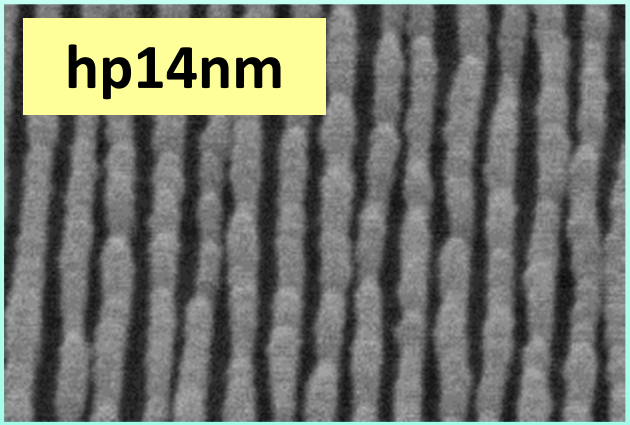


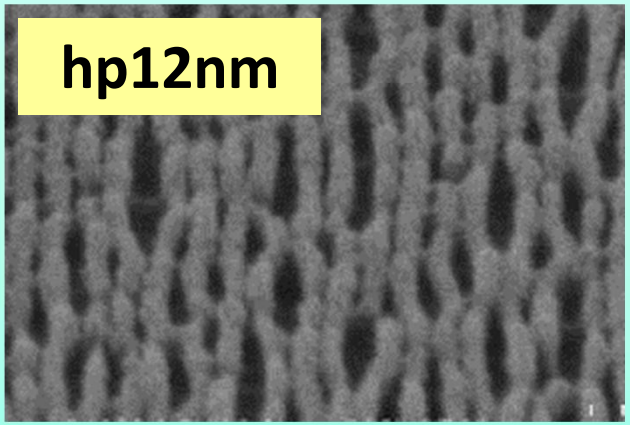
hp12nm

No image

DDR Pattern: PR-B (40nm) EUV exp. ⇒ DDR Process



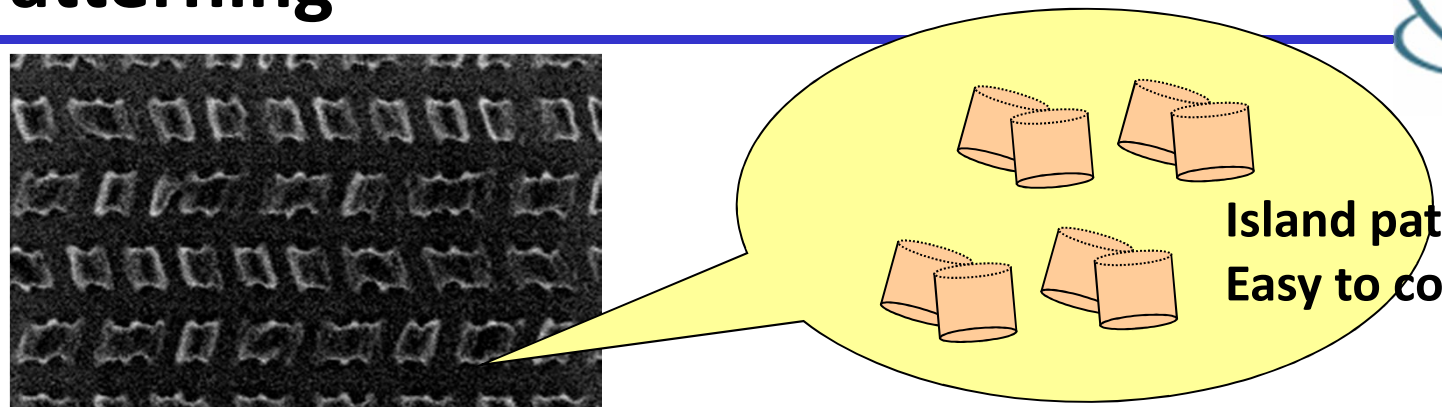




DDR pattern of hp 15nm was created with higher aspect ratio.
Hp 12nm was partly resolved!

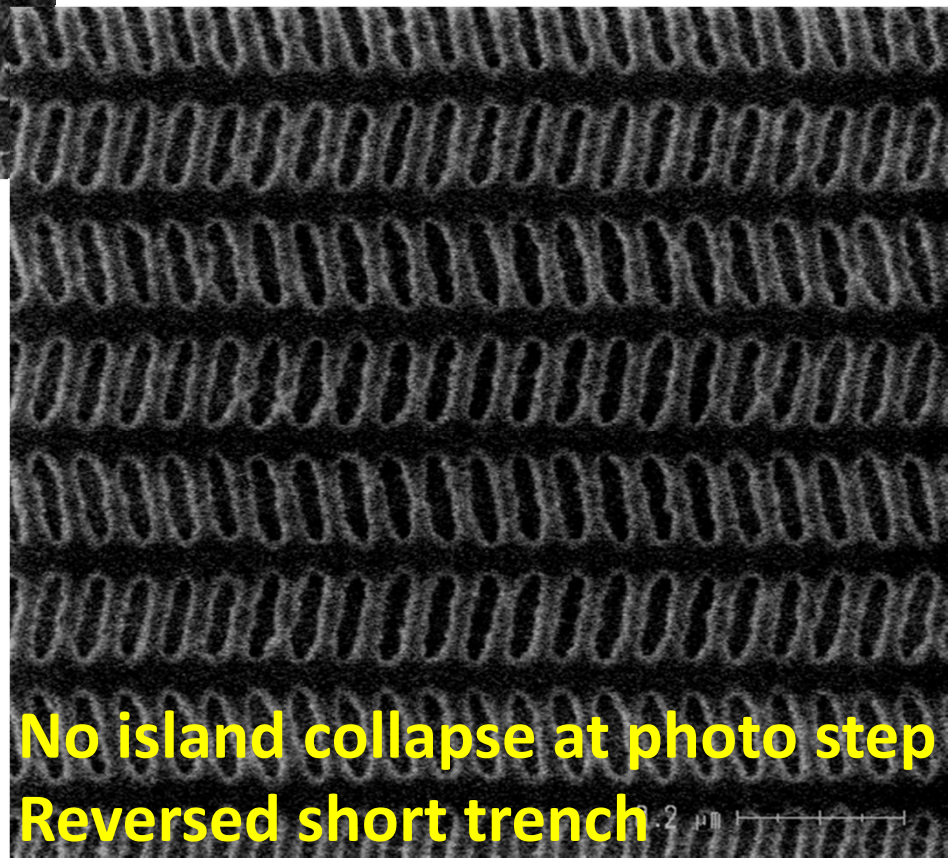
2D Patterning

Ref. PTD



DDR process

Negative tone image



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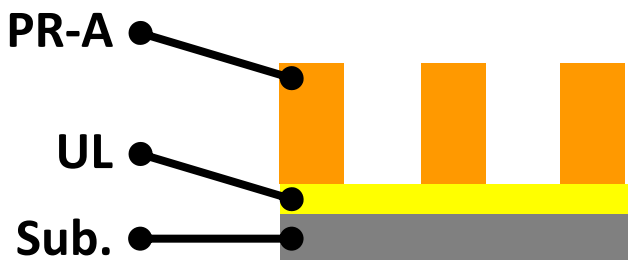
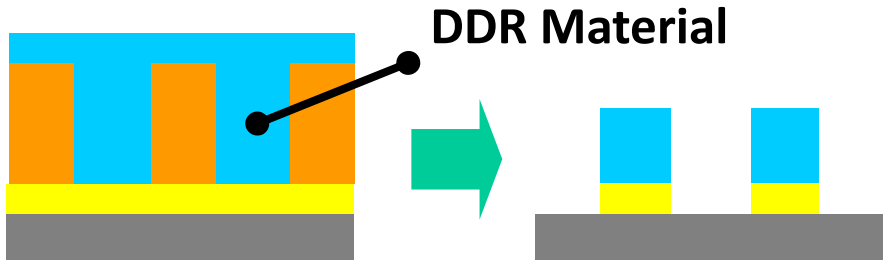
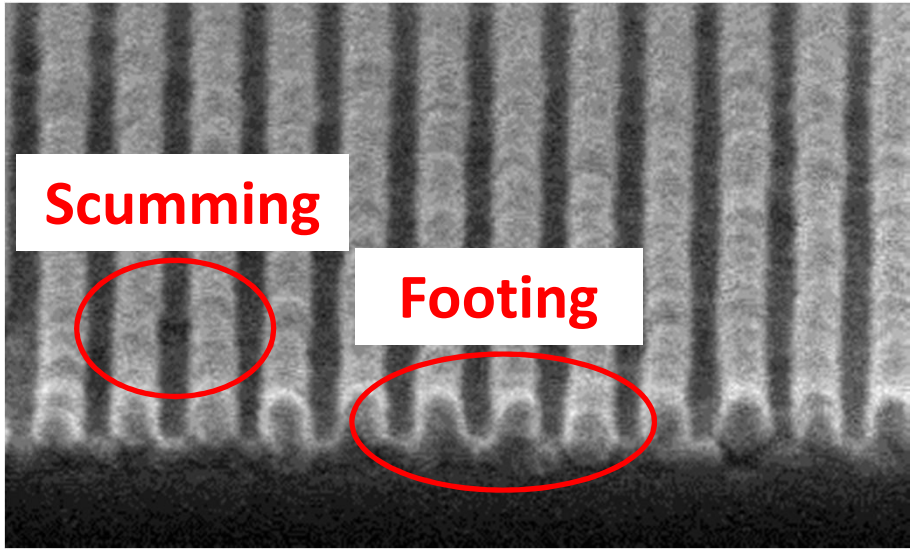
Comparison of the pattern profile @ hp 22nm

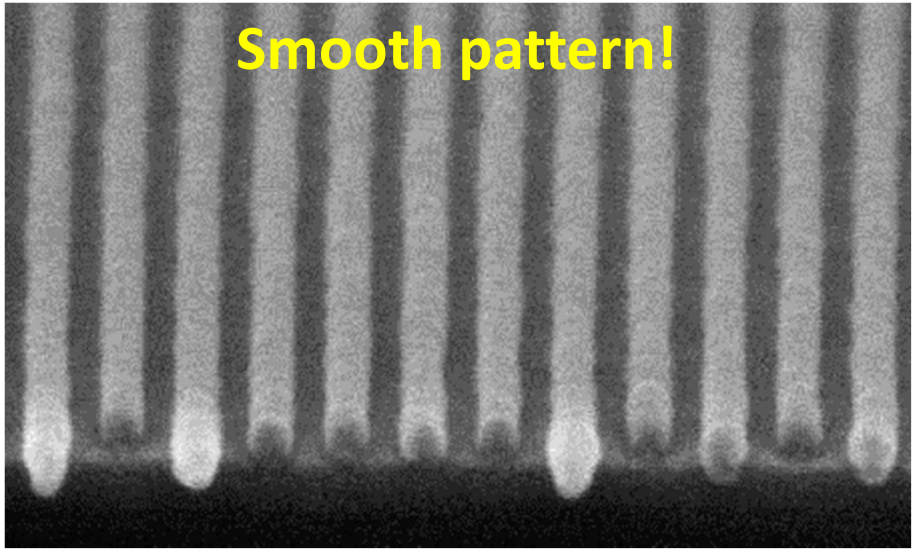
PR pattern



DDR pattern





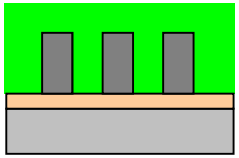


Footing, top roughness and scumming were improved.

⇒ DDR process showed potential to improve pattern profile.

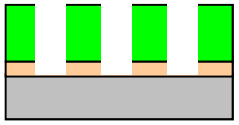
LWR study

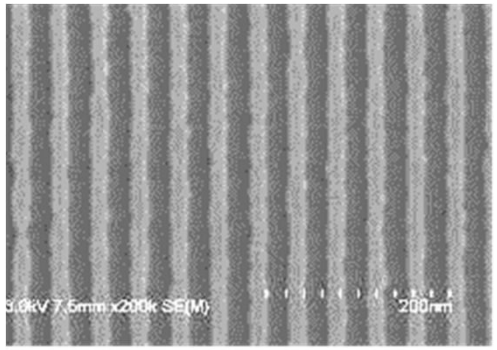
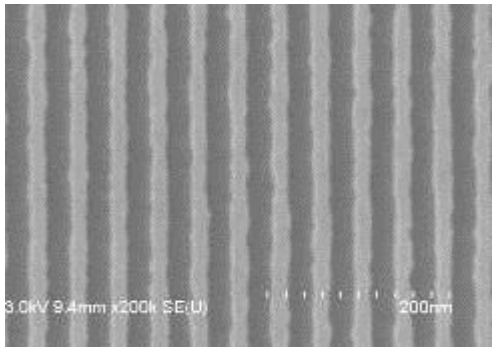
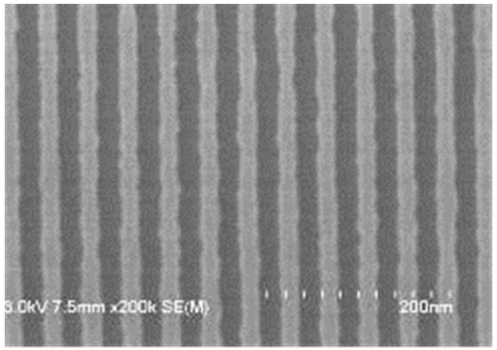
Baking temperature
Run1: No Baking
Run2: 100 degC.
Run3: 150 degC.



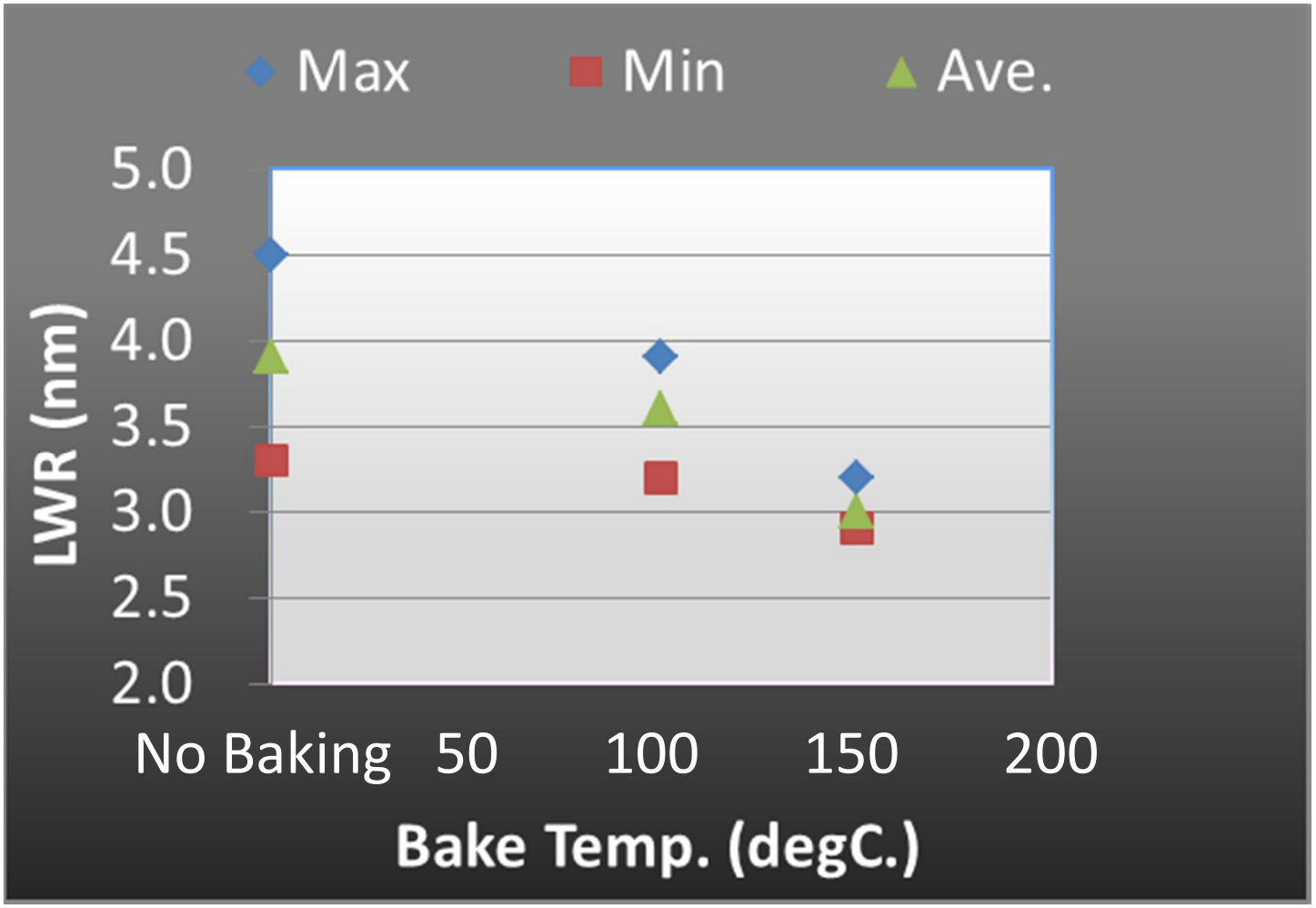
Etch back
PR removal

Measured LWR



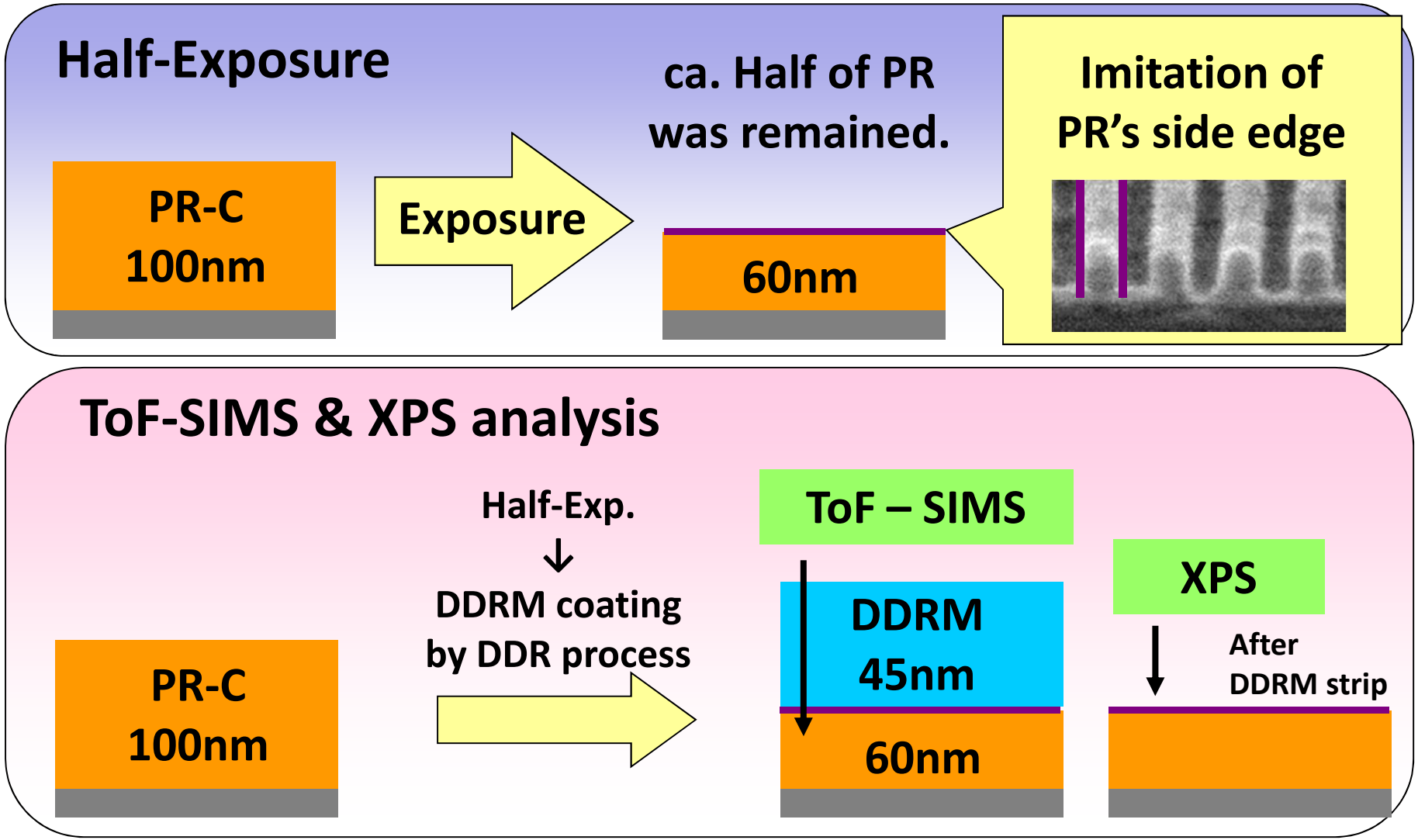
Baking Temp.	No Baking	100 degC. (STD Baking Temp.)	150 degC.
SEM image			
CD size	20.0 nm	19.2 nm	21.0 nm

LWR study



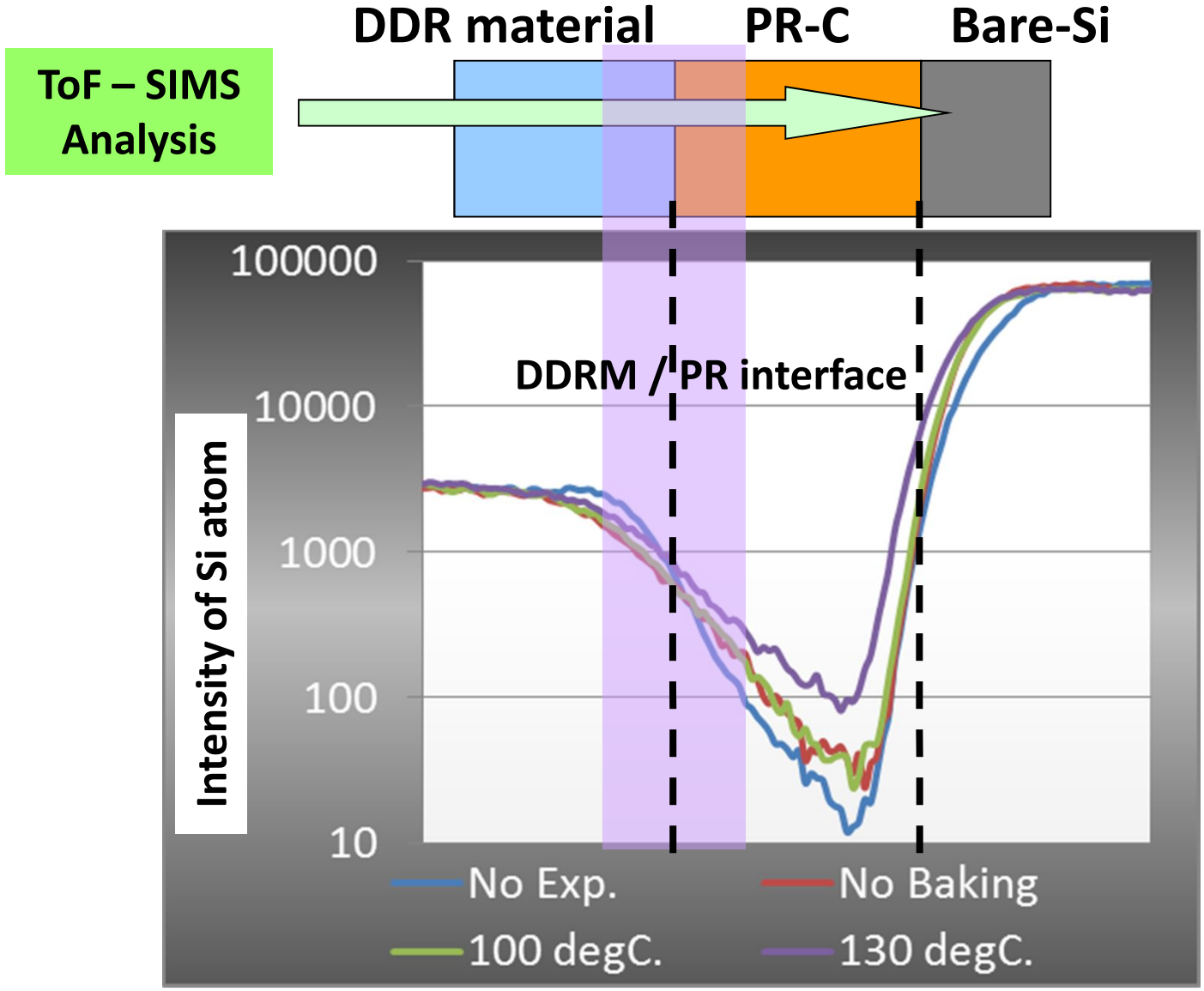
LWR was minimized according to the higher baking temp of DDRM.

Analysis of mixing layer



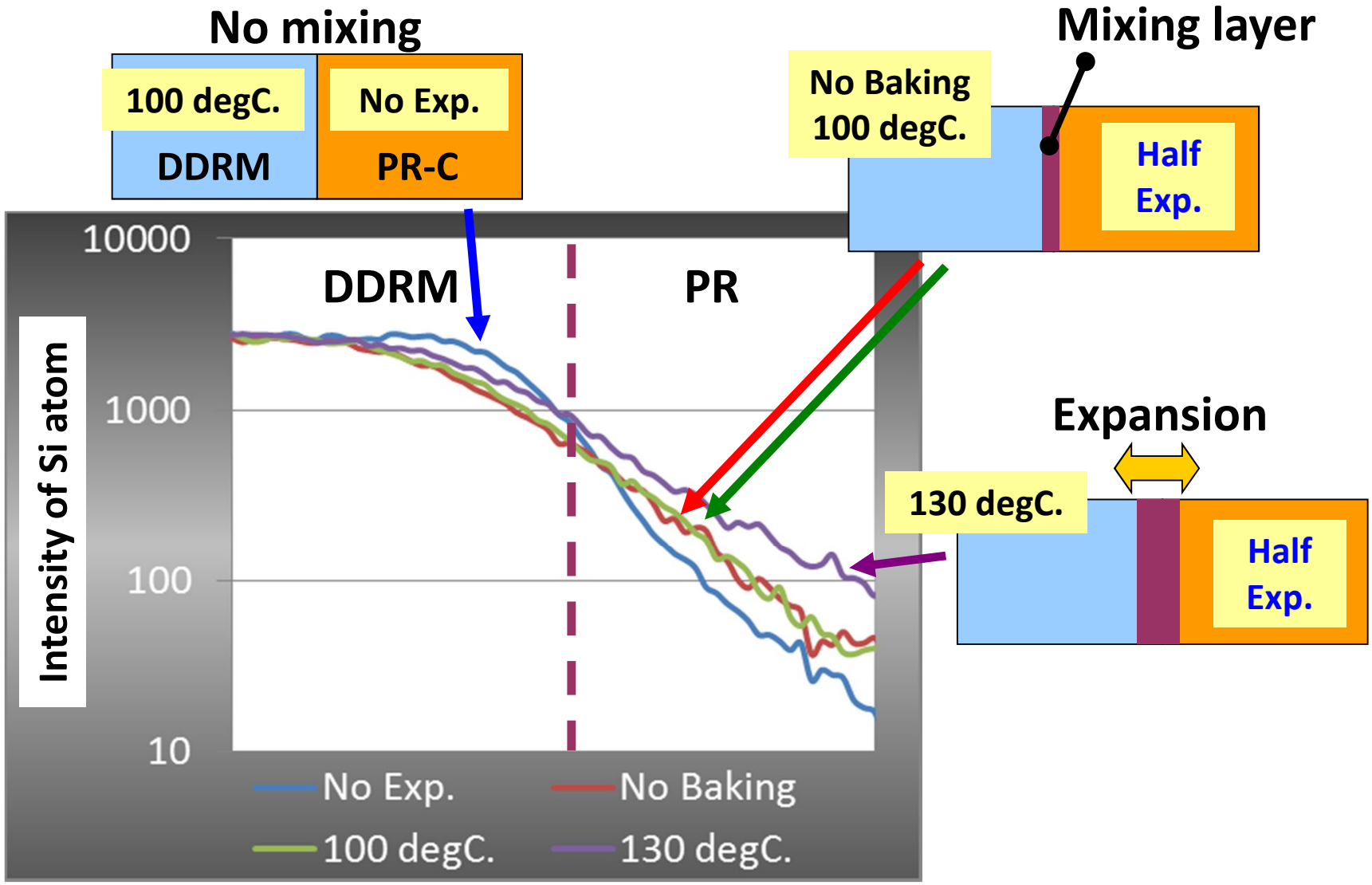
Dependence between LWR and mixing layer were investigated by ToF – SIMS & XPS analysis

Analysis of mixing layer by ToF - SIMS



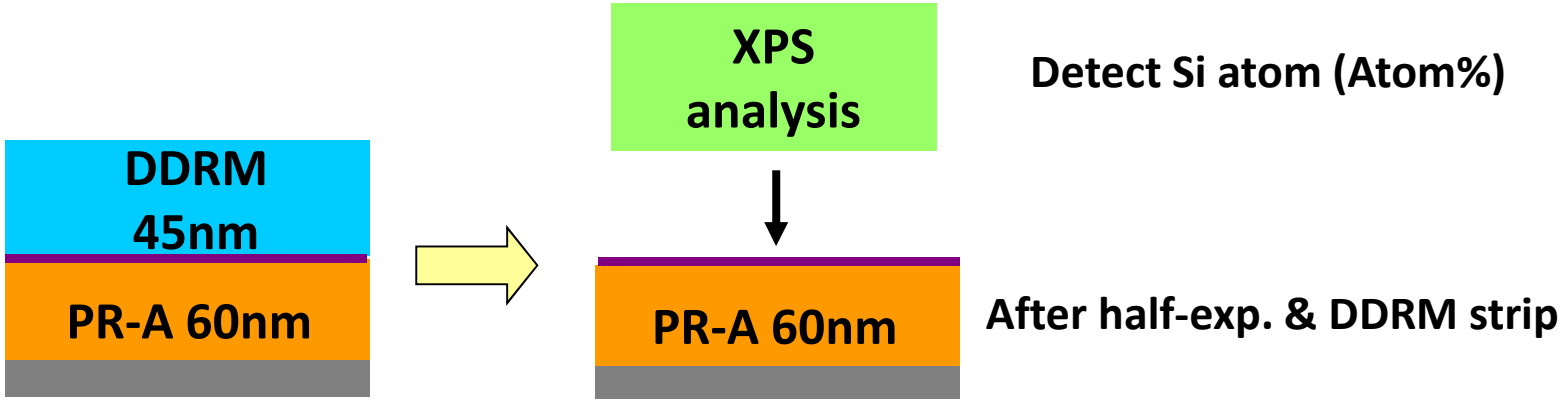
Monitored intensity of Si atom in the depth direction.

Analysis of mixing layer by ToF - SIMS



Formation and expansion of mixing layer was indicated!

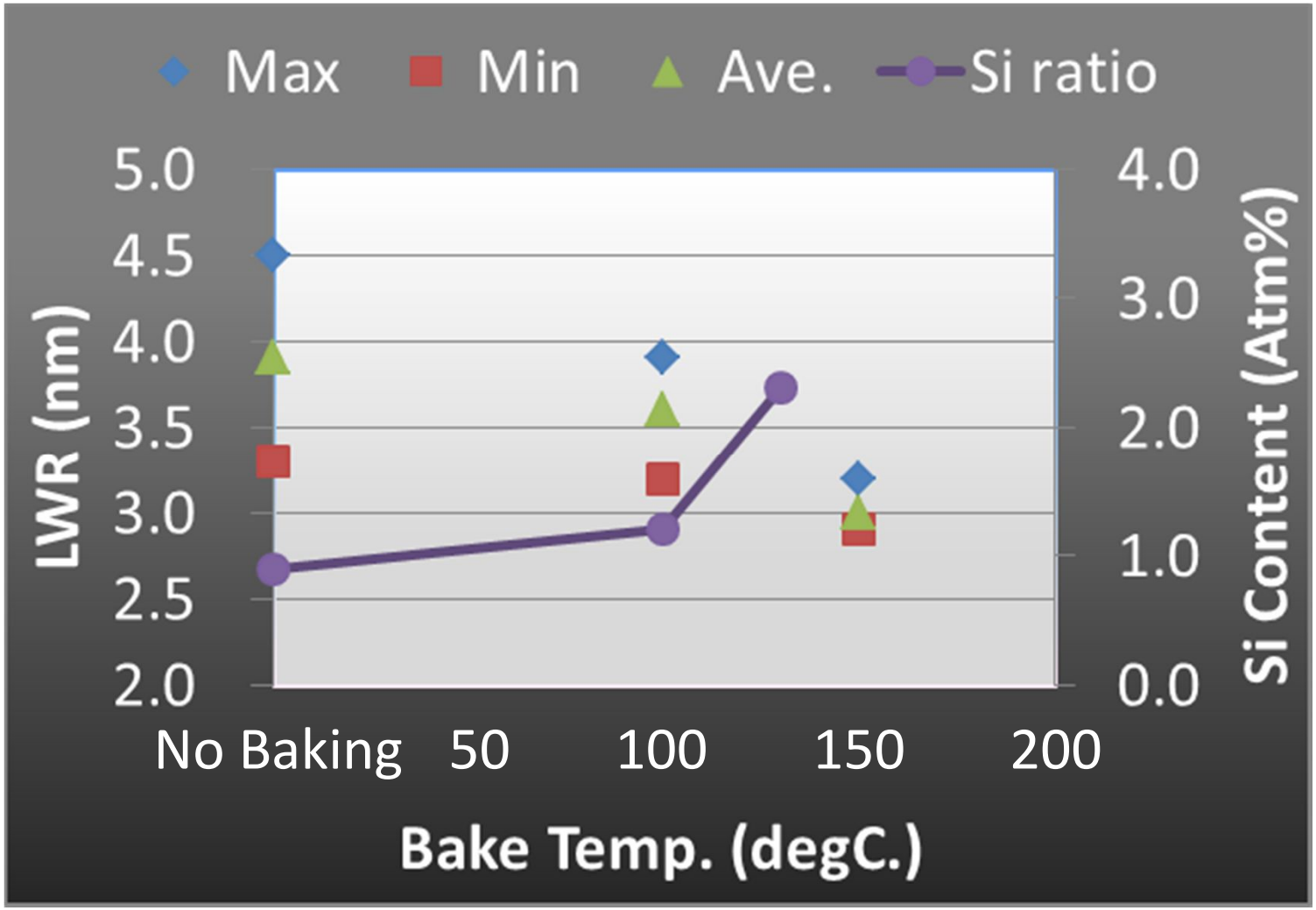
Analysis of mixing layer by XPS



Stacks	Bake Temp. of DDRM	Atom content (atom%)
		Si
PR-C only	-	0
PR-C (After DDRM Stripped)	No Baking	0.9
	100 degC.	1.2
	130 degC.	2.3

Formation of Mixing layer was indicated quantitatively.

Relationship between LWR and Si content



DDR process showed possibility to improve LWR by formation of mixing layer!

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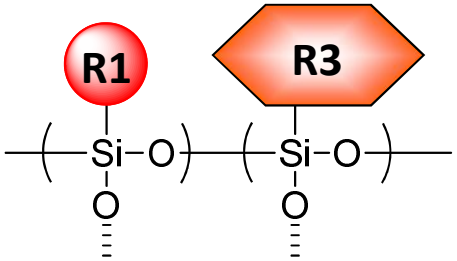
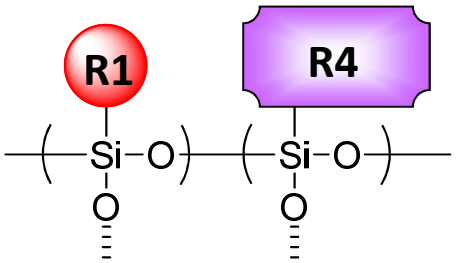
Candidates of the DDR materials

Sample name		NCR80	NCR81
Application		For PTD	For NTD
Polymer			
Functional unit		R1 Film property adjustment R3 Solubility for DIW Shelf life enhancement	R1 Film property adjustment R4 Solubility for org. solvents Shelf life enhancement
Solvent		Water type	Organic type
Etching Rate (vs. P.R.)	CF4	1.6	1.3
	O2	<0.1	<0.1
Solvent compatibility		DI water Developer PGME IPA 	MIBC Butyl acetate PGME Photo resists

Summary

- We developed new collapse free process named “DDR process”
- DDR process showed higher resolution compared to PTD process.
- DDR pattern showed straight profile without any scumming.
- LWR was improved by changing the baking condition of DDR material.
- Formation of mixing layer influenced the improvement of LWR.
- DDR materials have higher etch selectivity and good solvent compatibility.