Dry Development Rinse (DDR) Process and Material for Novel Pattern Shrink Technique in ArF-imm. Lithography.

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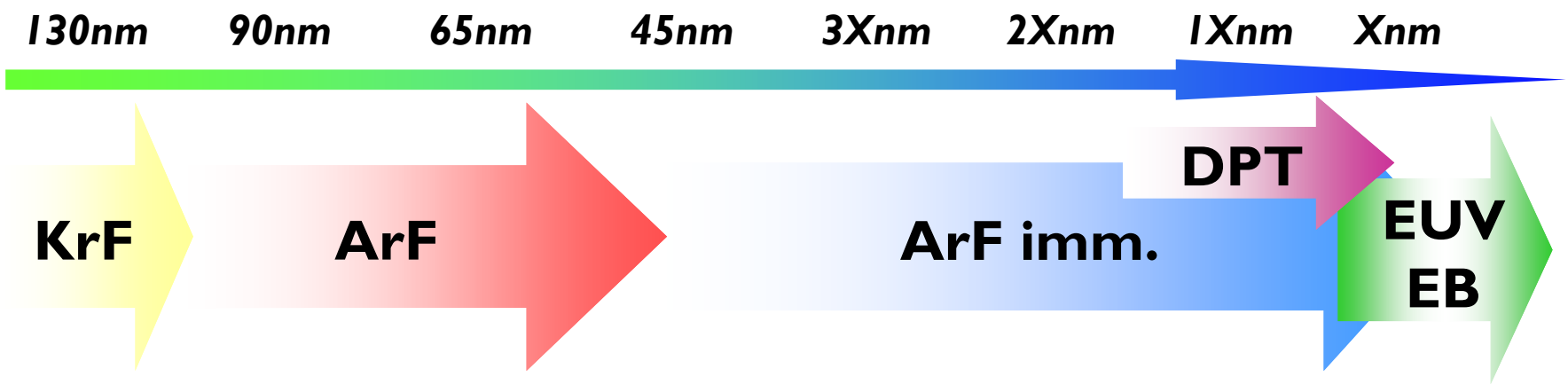
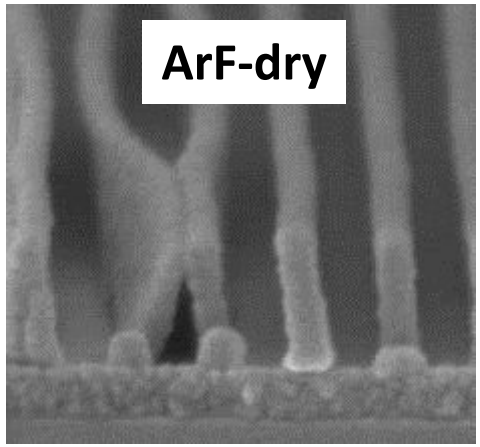
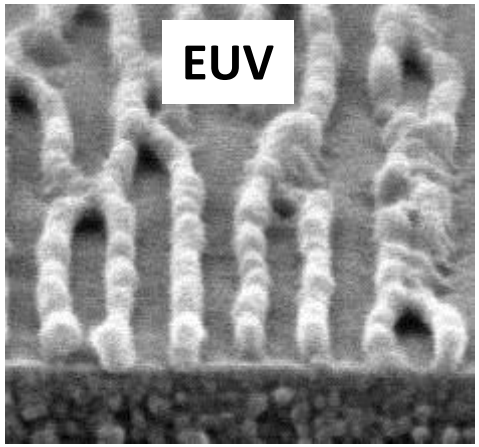
Introduction

Lithography technique

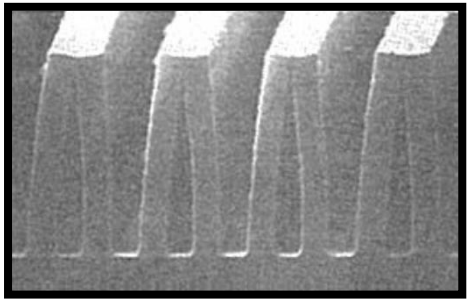




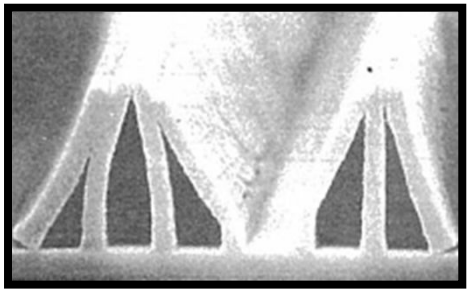


Pattern collapse is common issue in all generations and it became more sever in 1X nm generation.

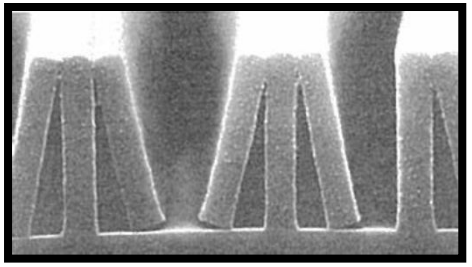
Root cause of the pattern collapse



Bending



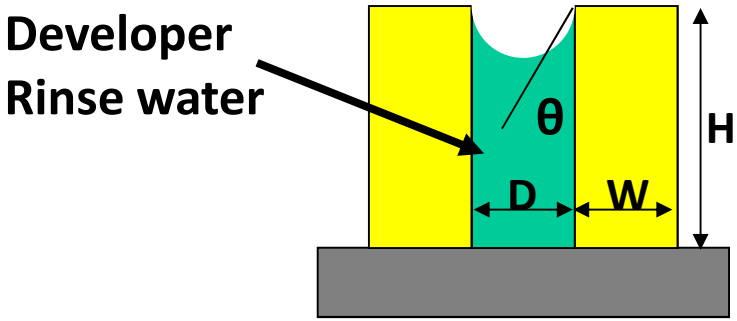
Breaking



Peeling

Root cause

Capillary force



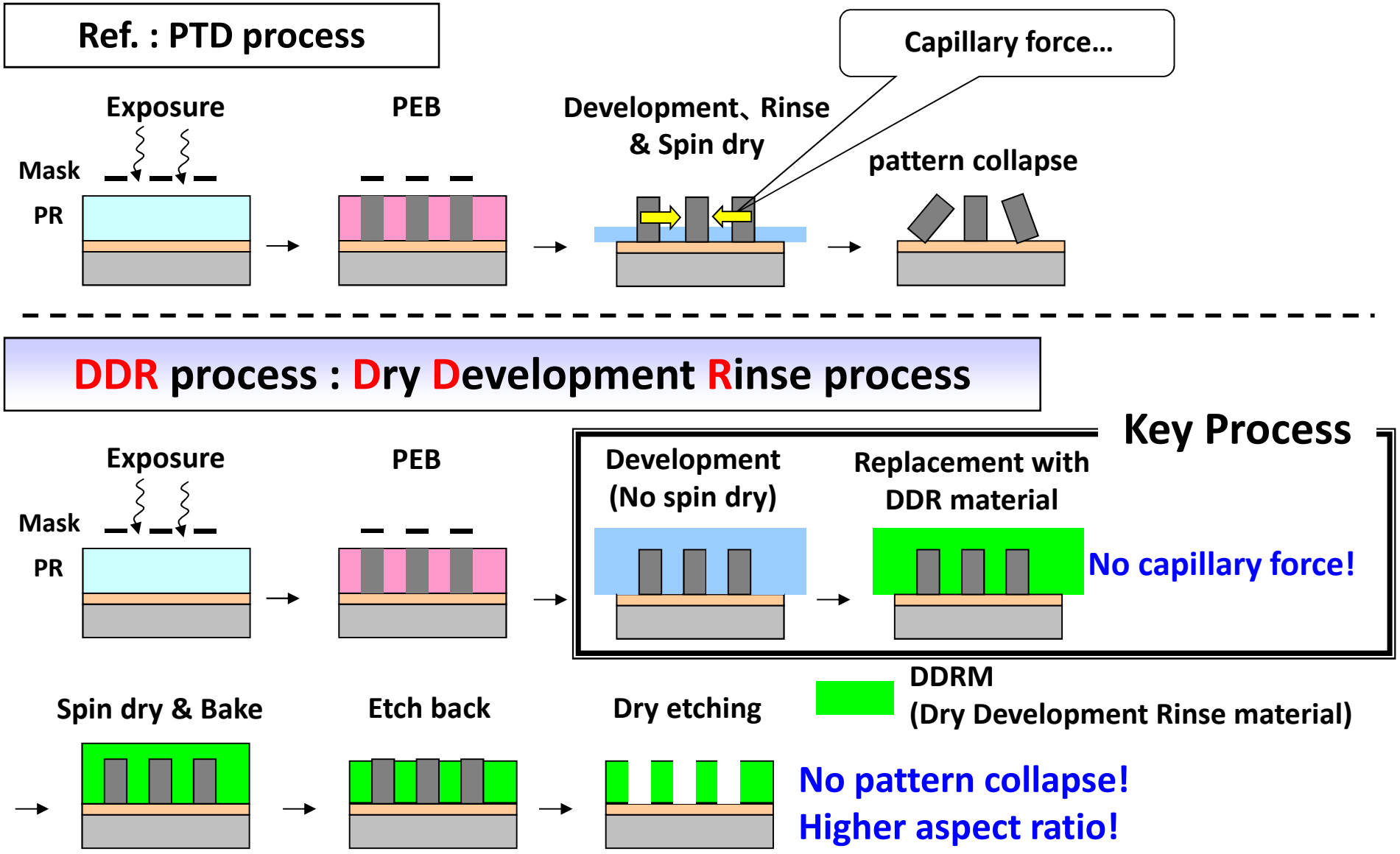
$$\sigma_{max}=6\gamma A^2/D\cdot\cos\theta$$

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.

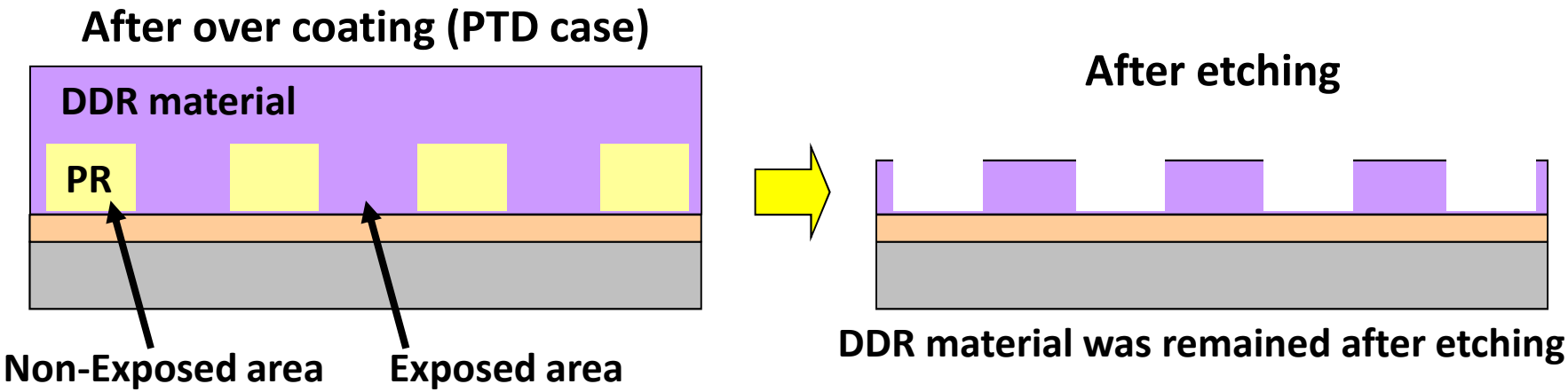
⇒Introduce "DDR process" which prevents capillary force.

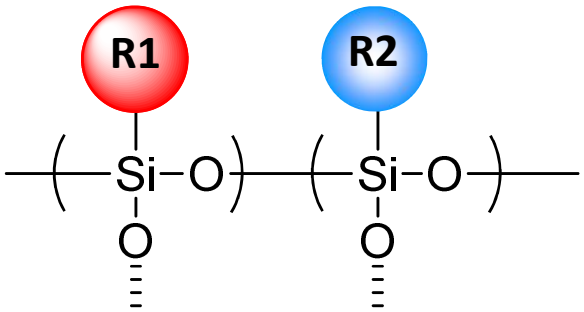
About DDR process



About DDR materials

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



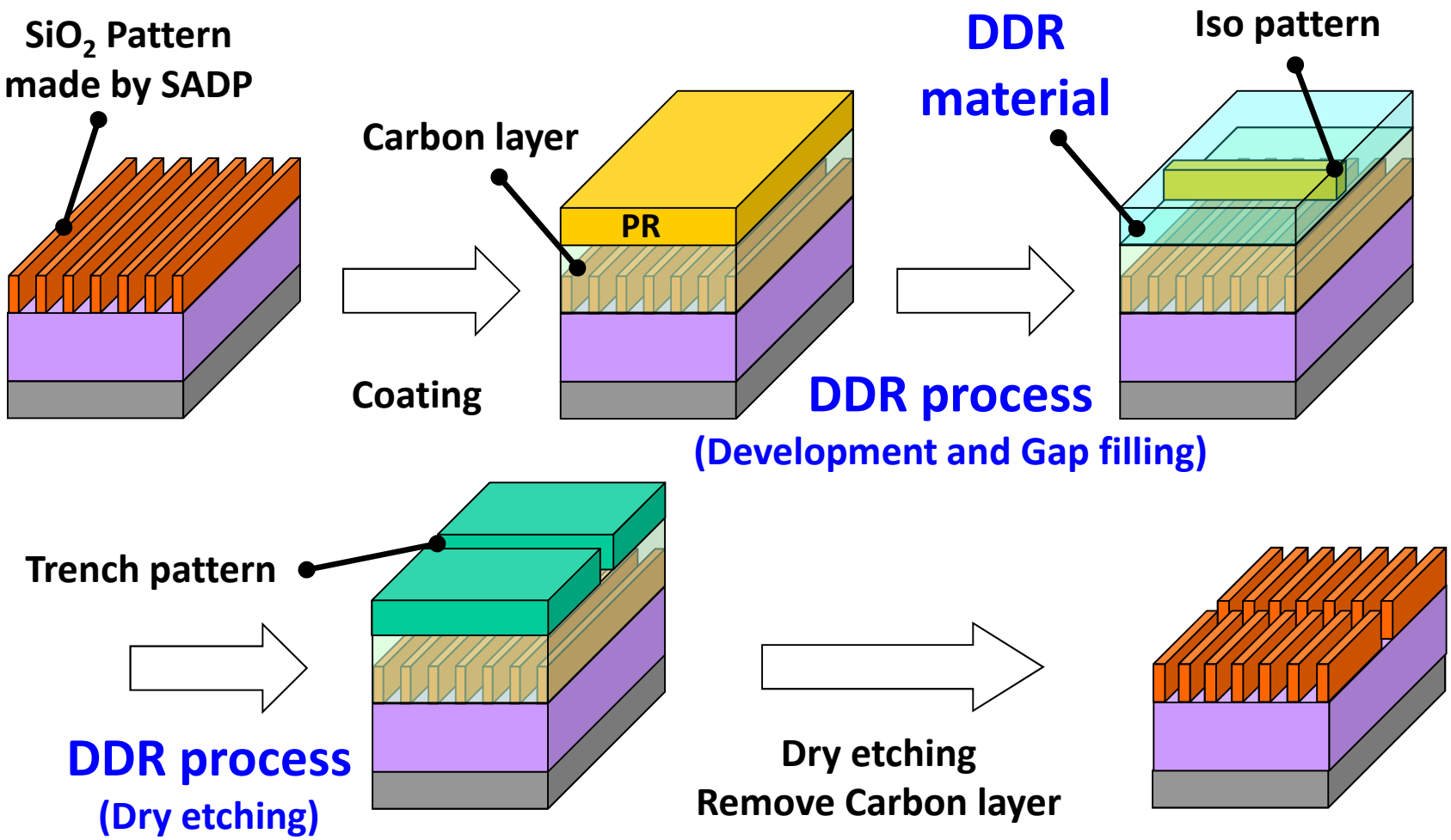


R1,2: Functional unit

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.

Application of DDR process to line cut process



DDR process has potential for application to line cut process because it is easy to create fine trench pattern.

DDR process with ArF-dry tool

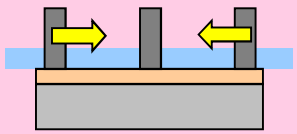
Stack bare Si / BARC-A (28nm, 205C/60s) / PR-C (210nm)

Target L65P260(L/S=1/3)

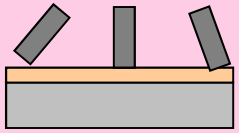
X-SEM: Ultimate Resolution + 2mJ/cm2

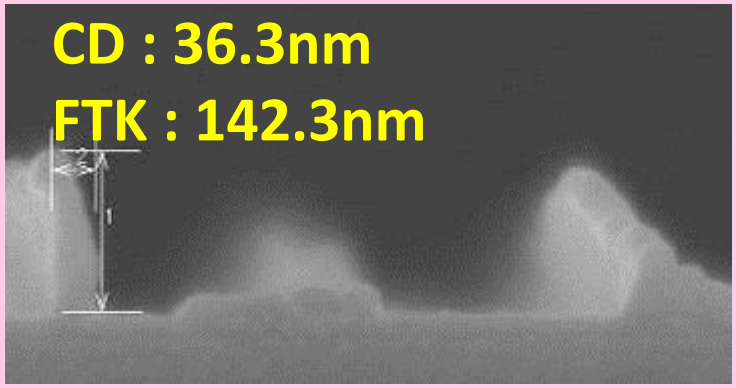
PTD process

Development、Rinse & Spin dry



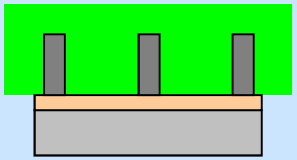
pattern collapse



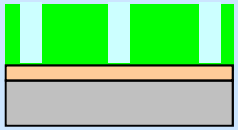


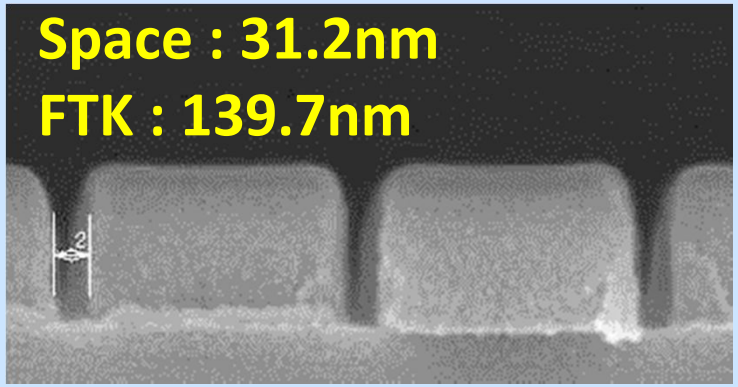
DDRP

Coat DDRM Spin dry



Etch back Dry etching





Trench pattern below 40nm space size could be obtained.

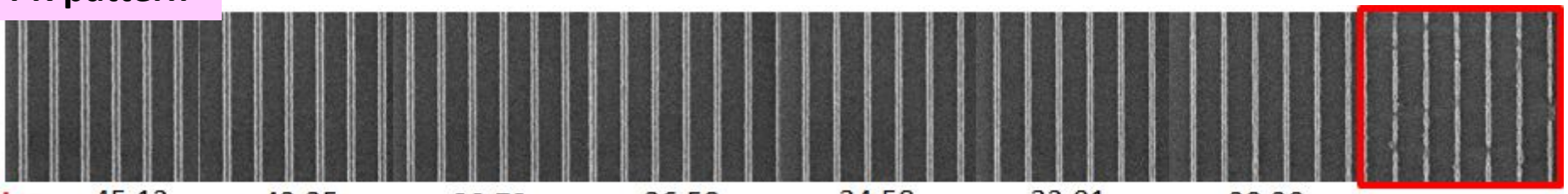
DDR process with ArF-imm. tool

Tool Exp. Tool: NXT1950i (ASML) / Coater Track: SOKUDO DUO (SCREEN)

Stack DDR material(FTK: 100nm) / STD PR-A(FTK: 100nm) / BARC-B (FTK: 85nm)

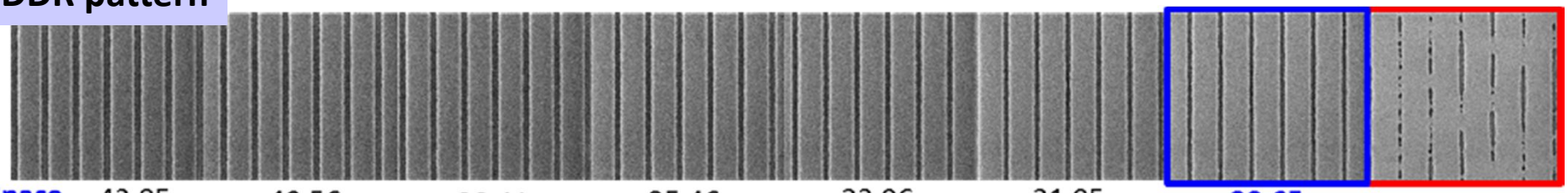
Target L45P180 (L/S=1/3)

PR pattern

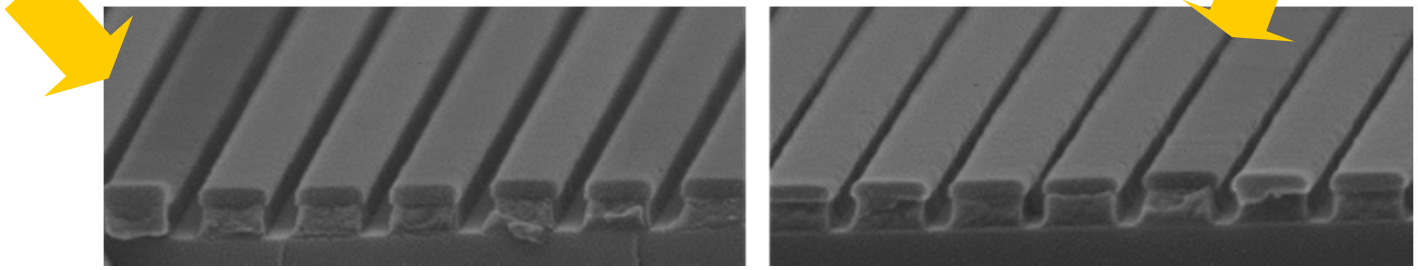


Line 45.12 42.35 39.72 36.58 34.58 32.01 29.20 -

DDR pattern



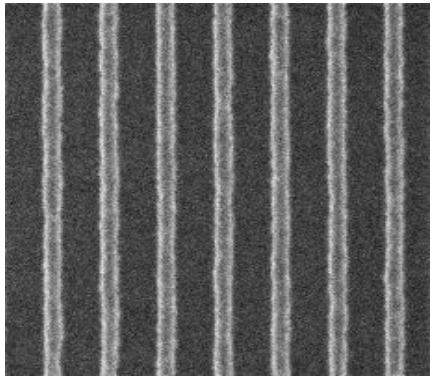
Space 42.85 40.56 38.41 35.46 33.96 31.05 28.65 -



Semi trench pattern below 30nm space could be created!

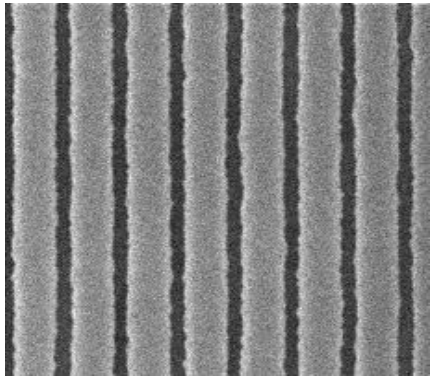
Pattern transfer

PR pattern



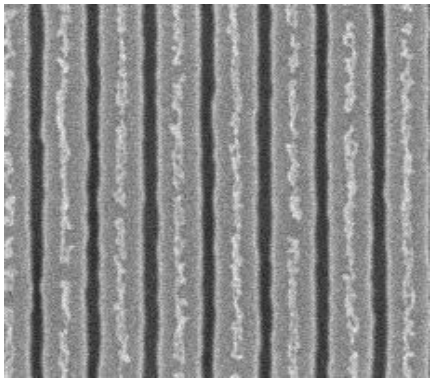
Line: 27.98nm

DDR pattern
Etch back & PR removal

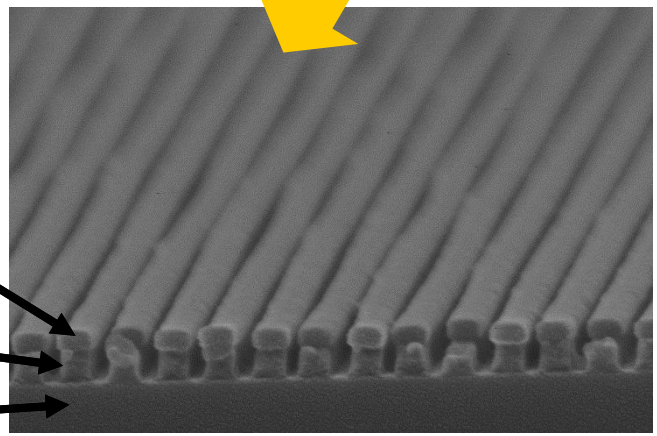


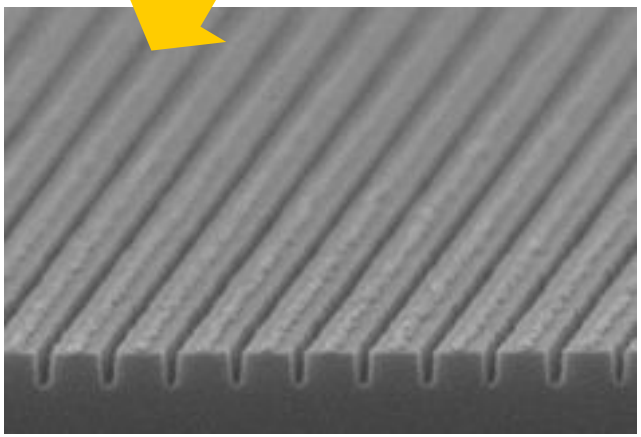
Space: 24.55nm

Substrate etching



Space: 21.8nm

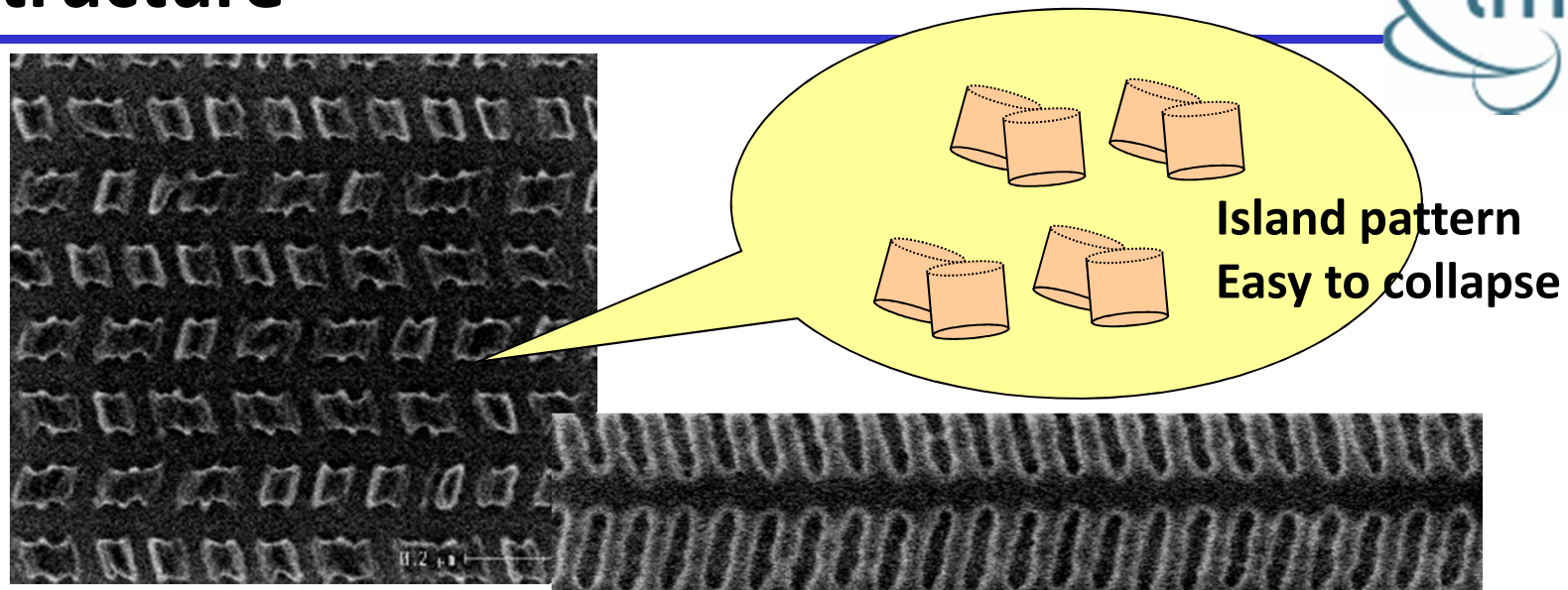




Pattern transfer was successfully achieved with narrower space size.

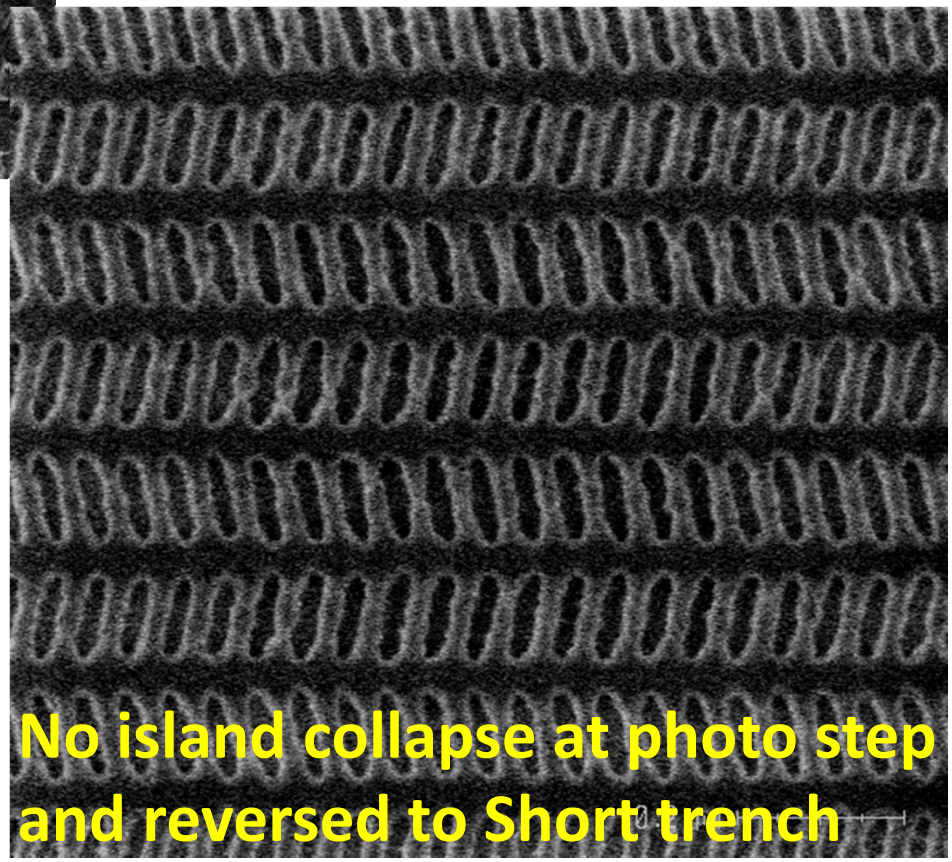
2D structure

Ref. PTD

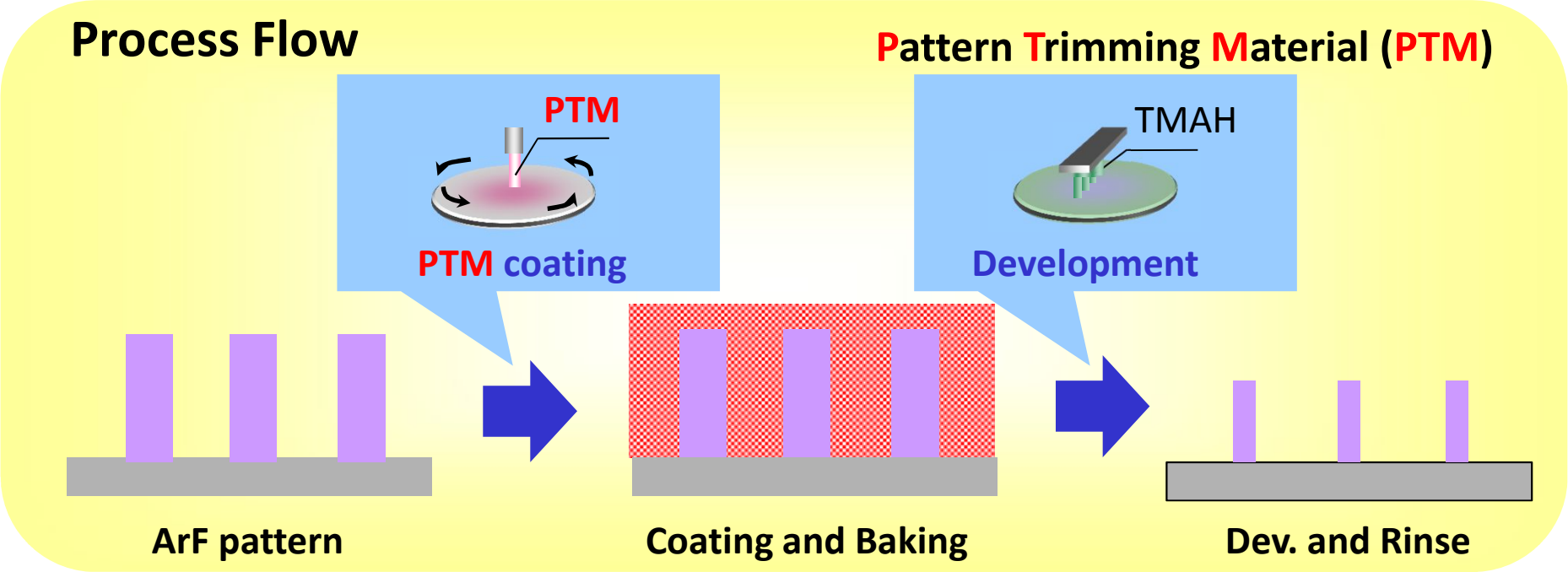


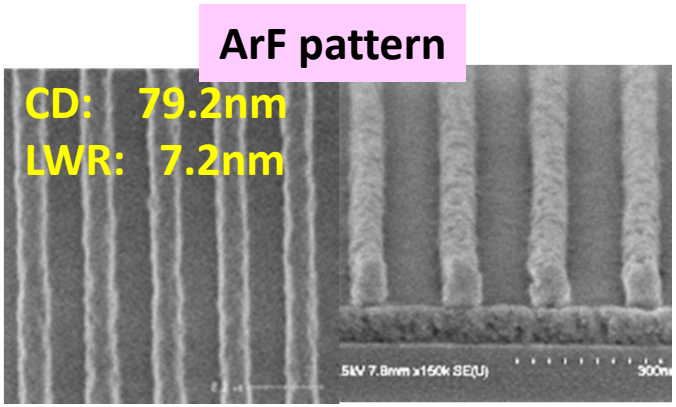
DDR process

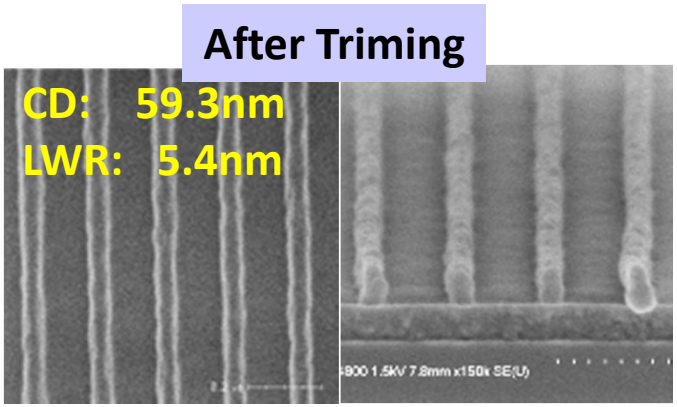
Negative tone image



Pattern Trimming Process



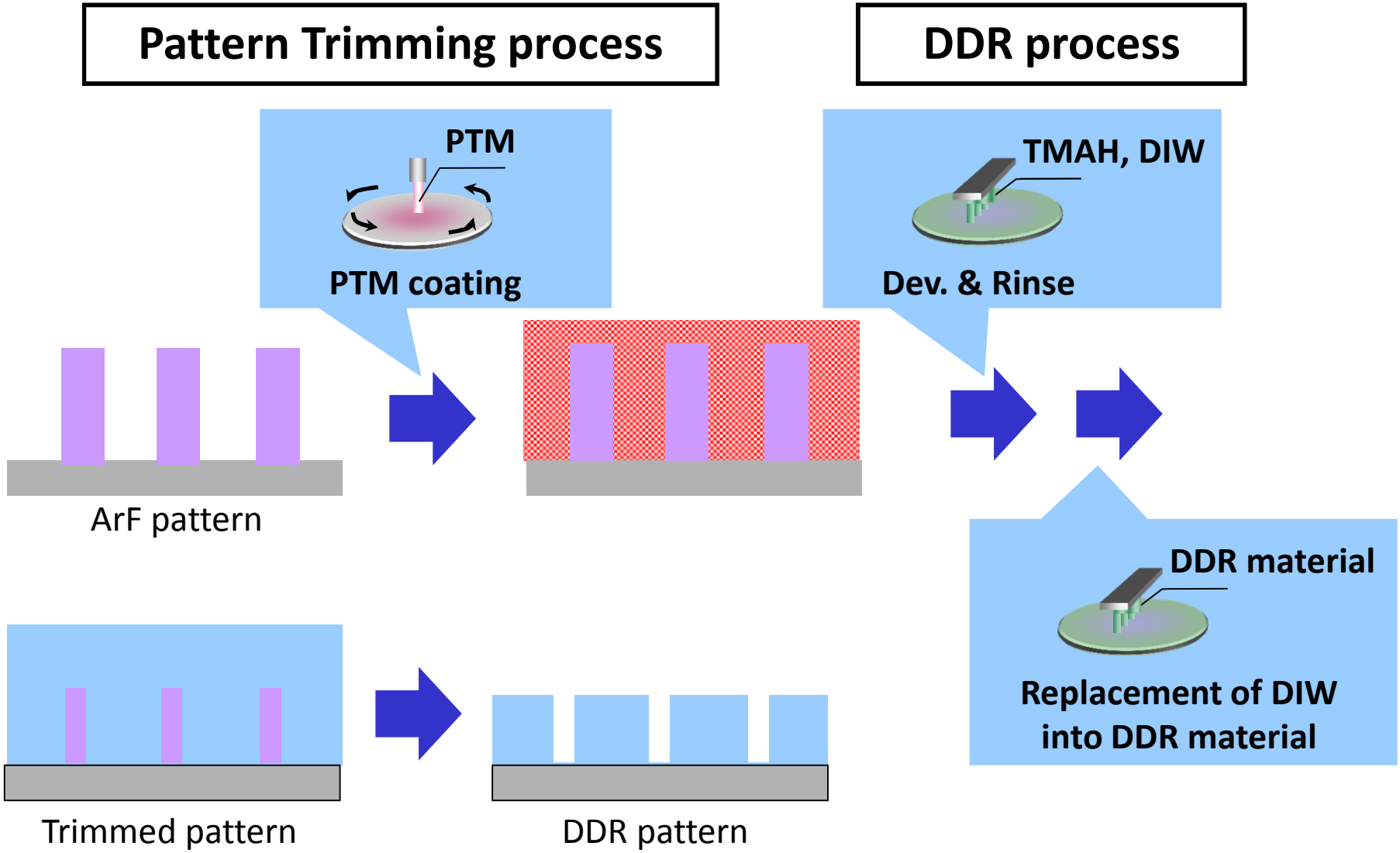




CD: -20nm
LWR: -2nm

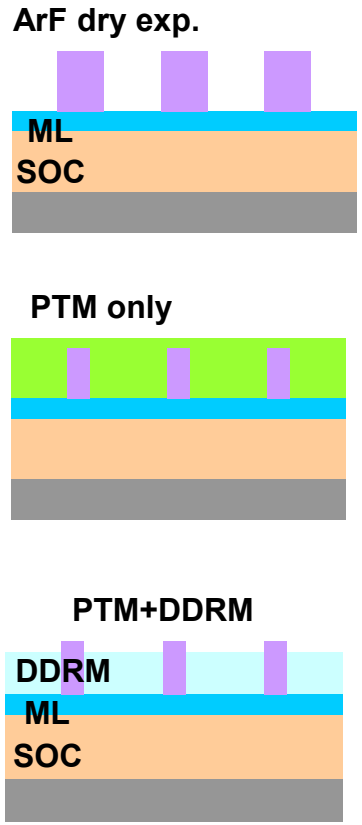
Pattern Trimming process showed superiority for CD size &LWR.

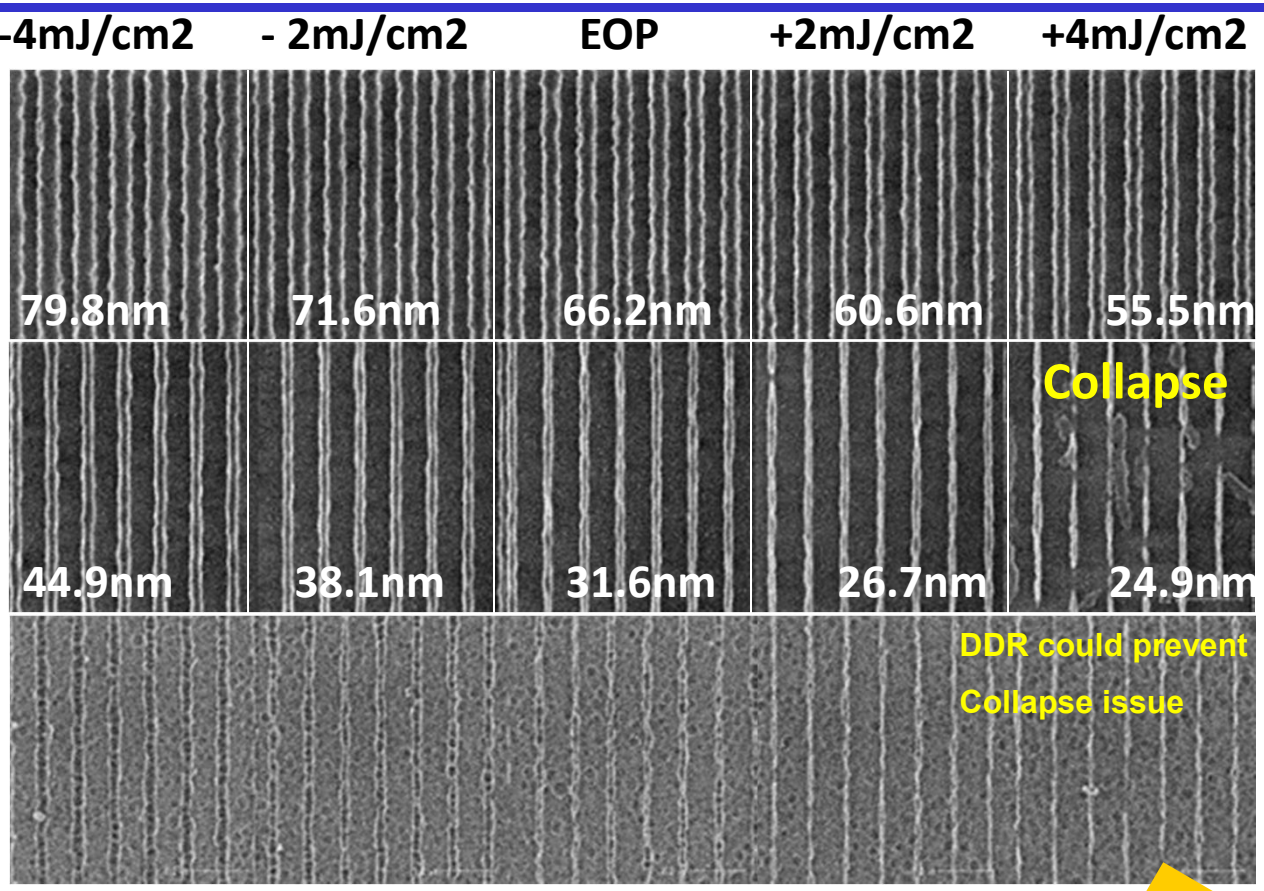
Pattern Trimming process & DDR process



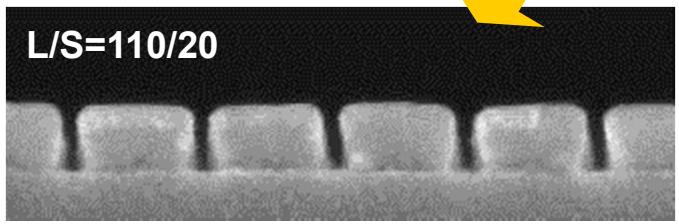
Pattern Trimming process & DDR process was demonstrated.

Pattern Trimming process & DDR process



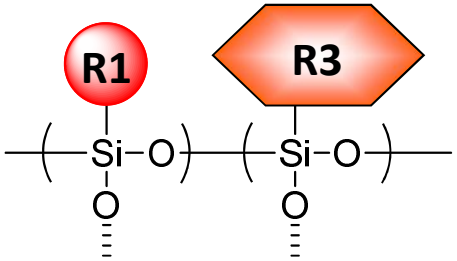
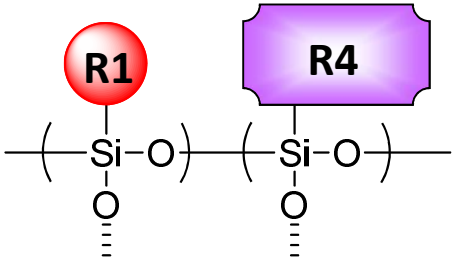


PR Removal



PT/DDR process could create 20nm Trench by ArF dry(NA=0.85)

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”
- Fine trench below 30nm could be created by DDR process with ArF-imm. tool.
- Pattern trimming was successfully achieved by pattern trimming process.
- Fine trench around 20nm could be created by combination of pattern trimming process and DDR process.
- Nissan DDR materials have higher etch selectivity and good solvent compatibility.