Alternative rinse solutions and after-development-rinse processes for EUVL

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Outline

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  - Rinse solutions on various resists
- Alternative rinse solution process
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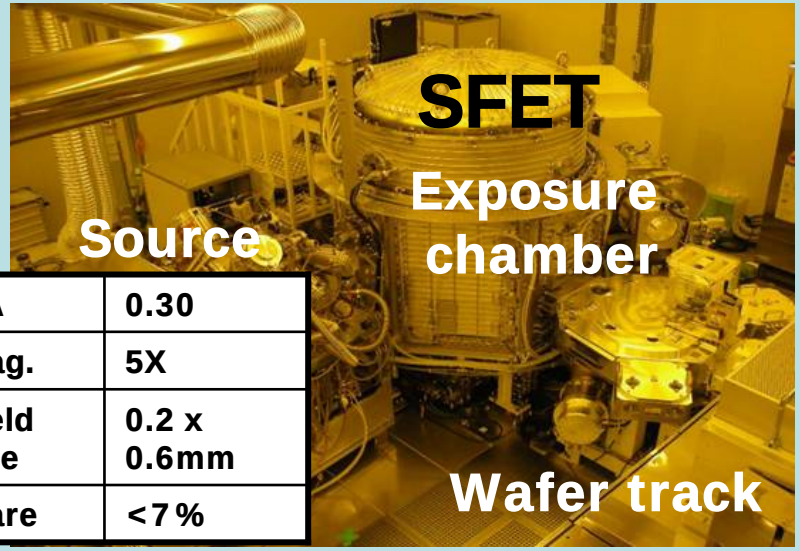
  - CD&LWR uniformity on rinse solution
- Summary

Abstract

As minimum feature sizes continue to get smaller in extreme ultraviolet lithography (EUVL), issues regarding higher aspect ratios and in effect, pattern collapse are encountered. Another main issue for these small feature sizes is the line width roughness (LWR) for presently available EUV resists. As a solution, the application of alternative rinse solutions and processes have been continuously investigated and applied for pattern collapse prevention. It has also been reported that these alternative rinse solutions are effective for reducing LWR. However, LWR values of present EUV resist are still too large in comparison to the required targets.

In this work, various **alternative rinse solutions** and **after-development-rinse process** for application in EUV lithography were investigated. Focusing on **LWR reduction** and **pattern collapse prevention**, the application of the most effective alternative rinse solutions and the optimization of after-development-rinse methods utilized will be presented.

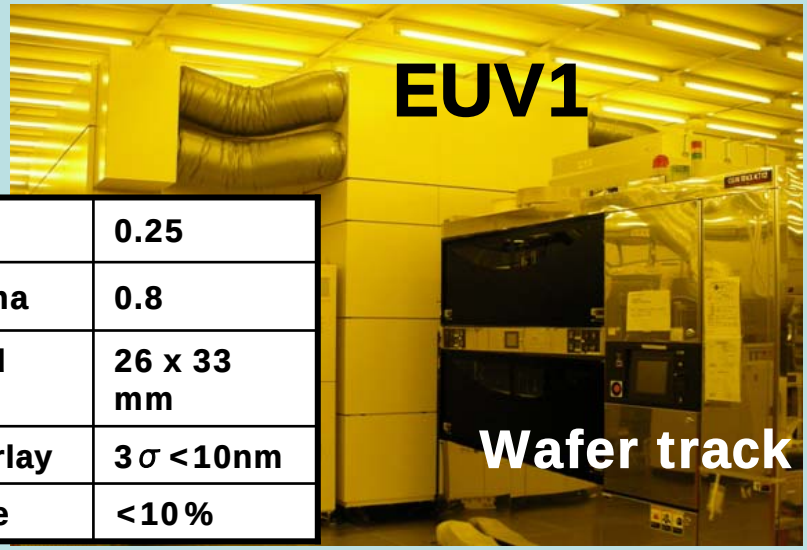
Experimental



NA	0.30
Mag.	5X
Field size	0.2 x 0.6mm
Flare	<7%

Fundamental test

Improvement of rinse materials
Fundamental evaluation of rinse process



NA	0.25
Sigma	0.8
Field size	26 x 33 mm
Overlay	3σ <10nm
Flare	<10%

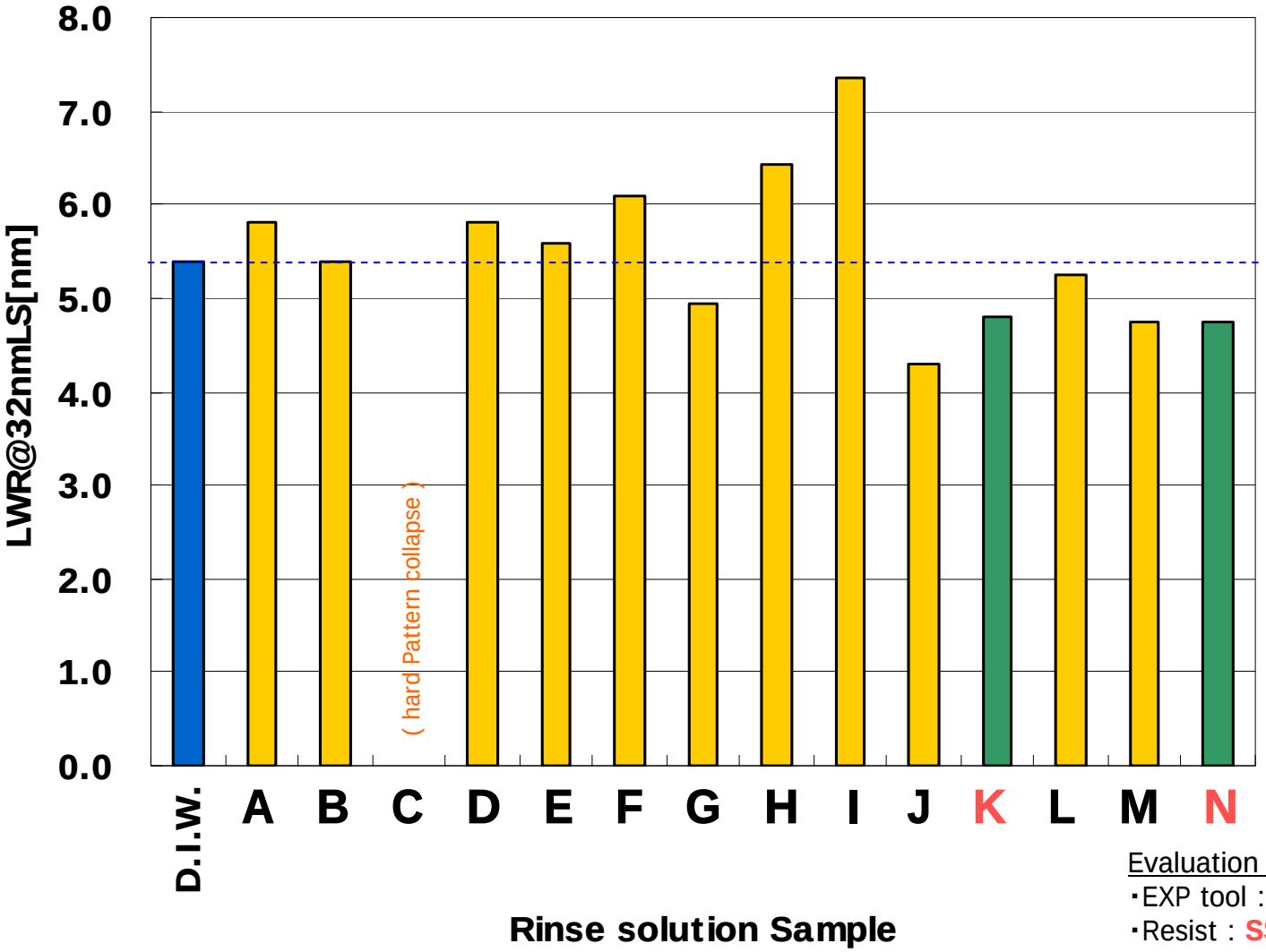
Productivity test

Wafer side evaluation

EUV Resist	SSR3, SSR4, SSR5, SMR613
Rinse solution	A, B, C, D, E, F, G, H, I, J, K, L, M, N

1. Alternative rinse solutions

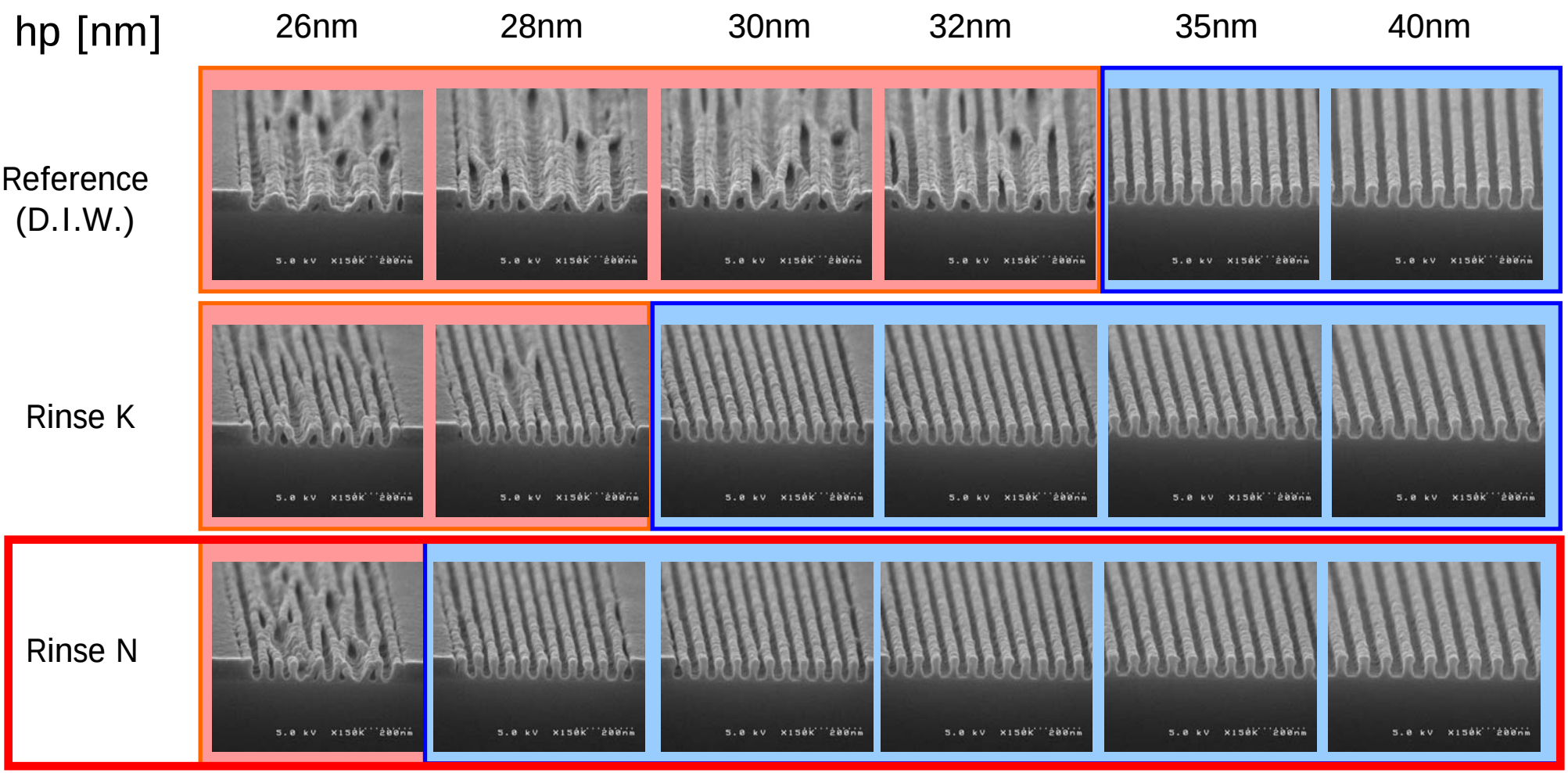
Various rinse solutions on LWR



Evaluation condition
- EXP tool :SFET NA0.3 Annular
- Resist : **SSR4**
- Developer : TMAH 2.38wt%

- LWR improved by rinse solutions.
- Resist pattern profile was good for rinse solution K,N.

Various rinse solutions on pattern collapse



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Evaluation condition
- EXP tool :SFET NA0.3 Annular
- Resist : SSR4 (Thickness:80nm)
- Developer : TMAH 2.38wt%

Pattern collapse improved by rinse solution N.

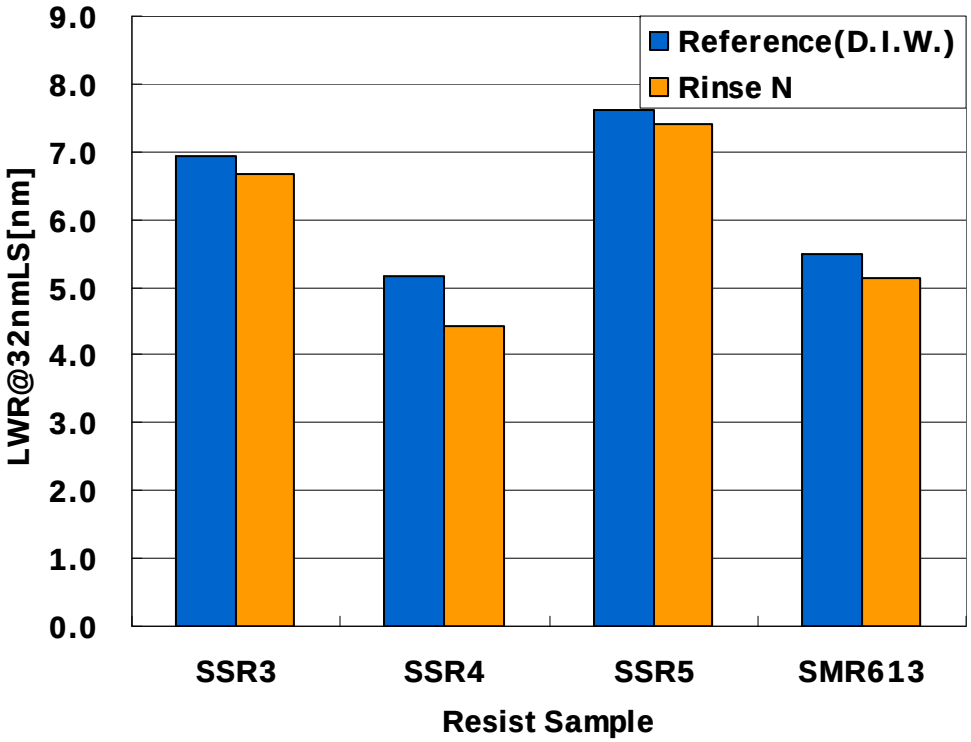
Summary of various rinse solutions

Rinse sample	Resolution limit [nm]	LWR@hp32nm [nm]	ΔCD@hp32nm [nm]	EL@hp35nm [%]
Reference (D.I.W.)	35	5.1	-	12.5
Rinse K	30	4.8	2.7	15.4
Rinse N	28	4.6	1.4	16.0

Evaluation condition
- EL (Exposure Latitude): CD±10%
- EXP tool :SFET NA0.3 Annular
- Resist : **SSR4**
- Developer : TMAH 2.38wt%

Rinse solution N was good performance.

Rinse solution N on various resists



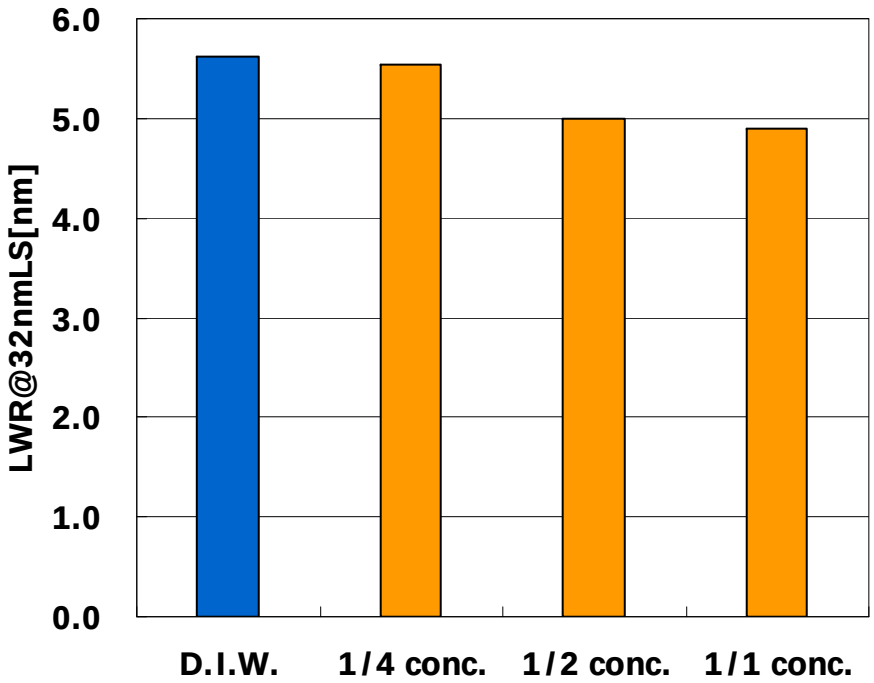
Resist	Resolution [nm]	LWR [nm]	ΔCD [nm]	EL[%]
SSR3	26 →25	6.9 →6.7	0.0	14.5 → 16.9
SSR4	35 →28	5.2 →4.4	1.4	12.7 →15.9
SSR5	26 →26	7.6 →7.4	0.2	10.1 → 10.9
SMR613	24 →24	5.5 →5.1	1.5	11.6 → 12.3

Evaluation condition
- EXP tool :SFET NA0.3 Annular
- Rinse solution : **Rinse N**
- Thickness : 80nm
- Developer : TMAH 2.38wt%

●LWR was improved for all resist.
●Pattern collapse was improved for some resist(SSR3,4).

2. Alternative rinse solution process

Various concentration of rinse solution K

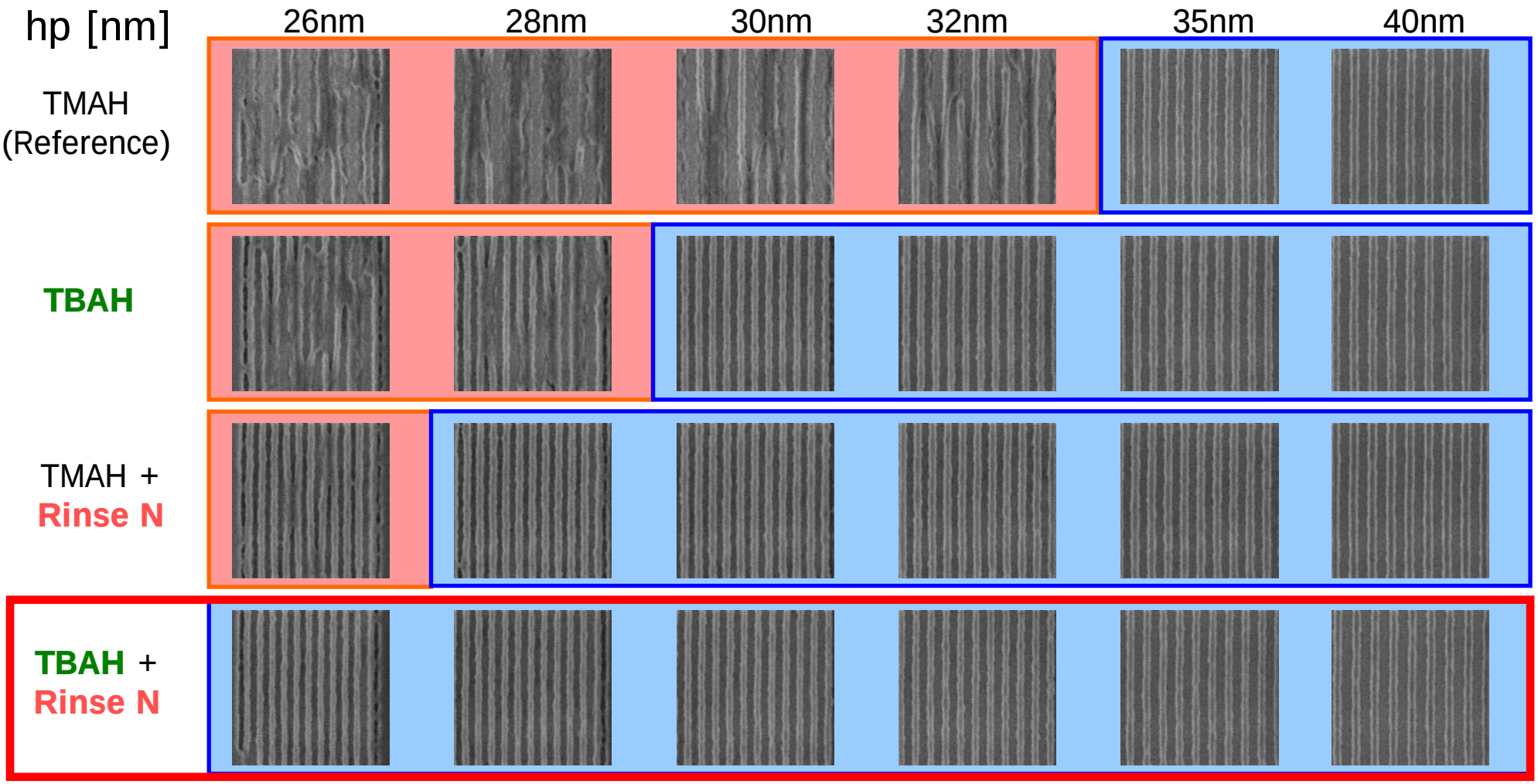


Rinse conc.	Resolution limit [nm]	LWR [nm]	ΔCD [nm]	EL[%]@ 35nm
D.I.W.	35	5.6	-	12.9
1/4 conc.	35	5.5	0.9	12.9
1/2 conc.	32	5.0	1.8	13.4
1/1 conc.	30	4.9	2.6	14.3

Evaluation condition
- EXP tool :SFET NA0.3 Annular
- Resist : **SSR4**(Thickness 80nm)
- Rinse solution : **Rinse K**
- Developer : TMAH 2.38wt%

LWR was improved for high concentration.

Various developer solutions on pattern collapse



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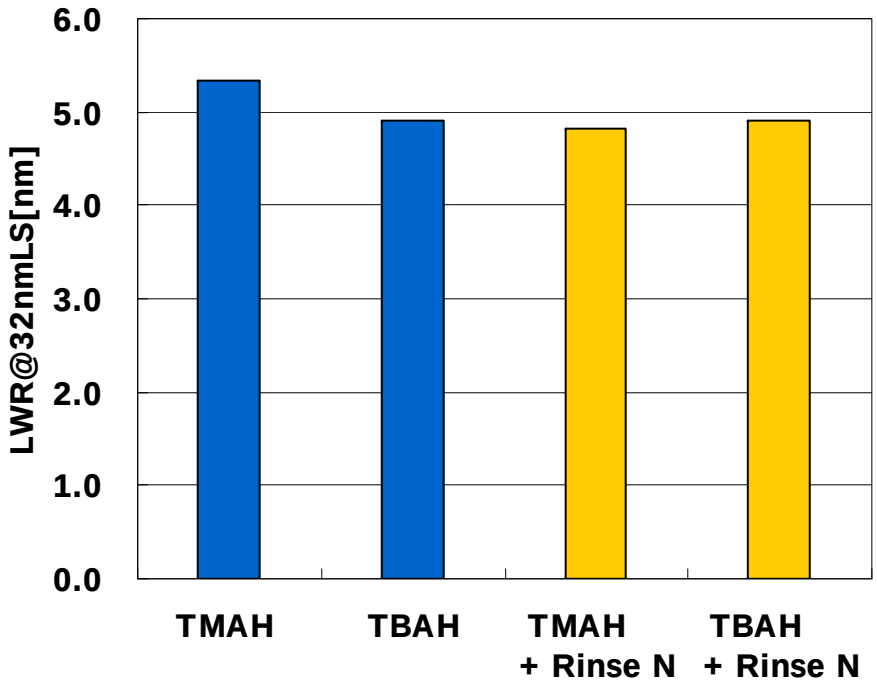
Evaluation condition

- EXP tool :SFET NA0.3 Annular
- Resist : SSR4(Thickness 80nm)
- Rinse solution : Rinse N
- Developer : TMAH 2.38wt%,TBAH 2.38wt%

Best results were obtained using the combination of TBAH and Rinse solution N.

Summary of various developer solutions



Condition	Resolution limit [nm]	LWR [nm]	ΔCD [nm]	EL[%]@ 35nm
TMAH	35	5.3	-	12.3
TBAH	30	4.9	-	12.4
TMAH+ Rinse N	28	4.8	1.6	15.9
TBAH+ Rinse N	26	4.9	-0.9	15.8

Evaluation condition
- EXP tool :SFET NA0.3 Annular
- Resist : **SSR4**(Thickness 80nm)
- Rinse solution : **Rinse N**
- Developer : TMAH 2.38wt%,**TBAH**2.38wt%

●Pattern collapse was prevented using the combination of TBAH and Rinse solution N. (resulting good resolution)

●LWR was improved by TBAH and Rinse N.

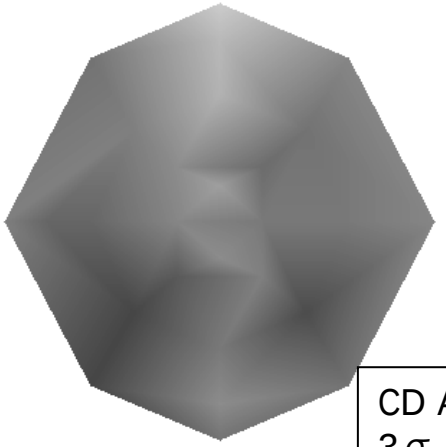
CD&LWR uniformity on rinse solution (EUV1)

Selete

Reference (D.I.W.) | Rinse N

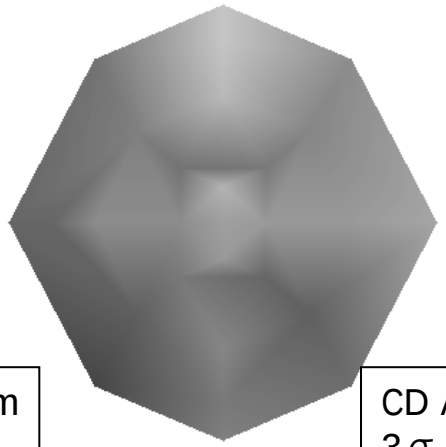
300mm φ
Intra-Wafer

CD MAP



CD AVG:25.7nm
3σ :1.5nm

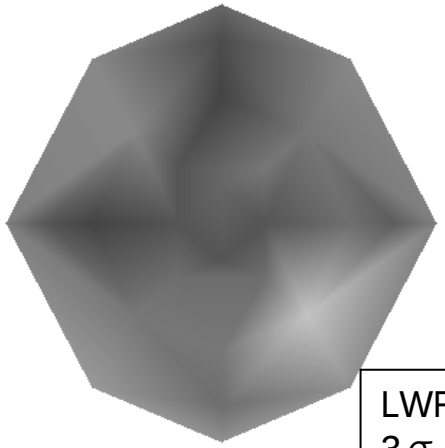
24.0 28.0



CD AVG:26.1nm
3σ :1.4nm

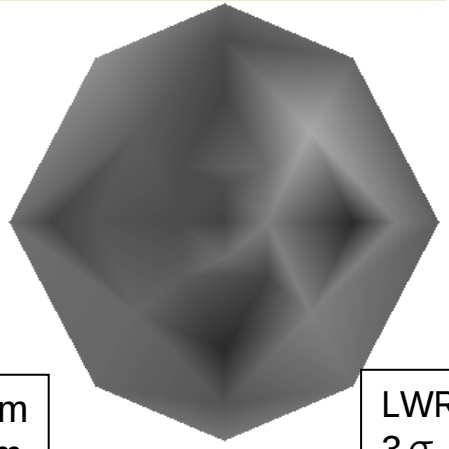
24.0 28.0

LWR MAP



LWR AVG:6.8nm
3σ :1.0nm

5.5 8.5



LWR AVG:6.6nm
3σ :0.9nm

5.5 8.5

Evaluation condition
- EXP tool :**EUV1** static/Conv.
- Resist : **SSR4**(Thickness 50nm)
- CD 26nm (hp35nm 1:1)
- measurement point : 29point
- Developer : TMAH 2.38wt%
- Wafer : 300mm in diameter

CD&LWR uniformity was almost the same. (No negative impact)

Summary

- Alternative rinse solutions & process were evaluated and presented.

- Alternative rinse solution
  - LWR & Pattern collapse was improved for **Rinse solution K and N**.

- Alternative rinse solution process
  - Combination of **TBAH and Rinse solution N** was good for LWR and pattern collapse prevention .
  - CD&LWR uniformity was almost the same. (No negative impact)

Acknowledgements

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