

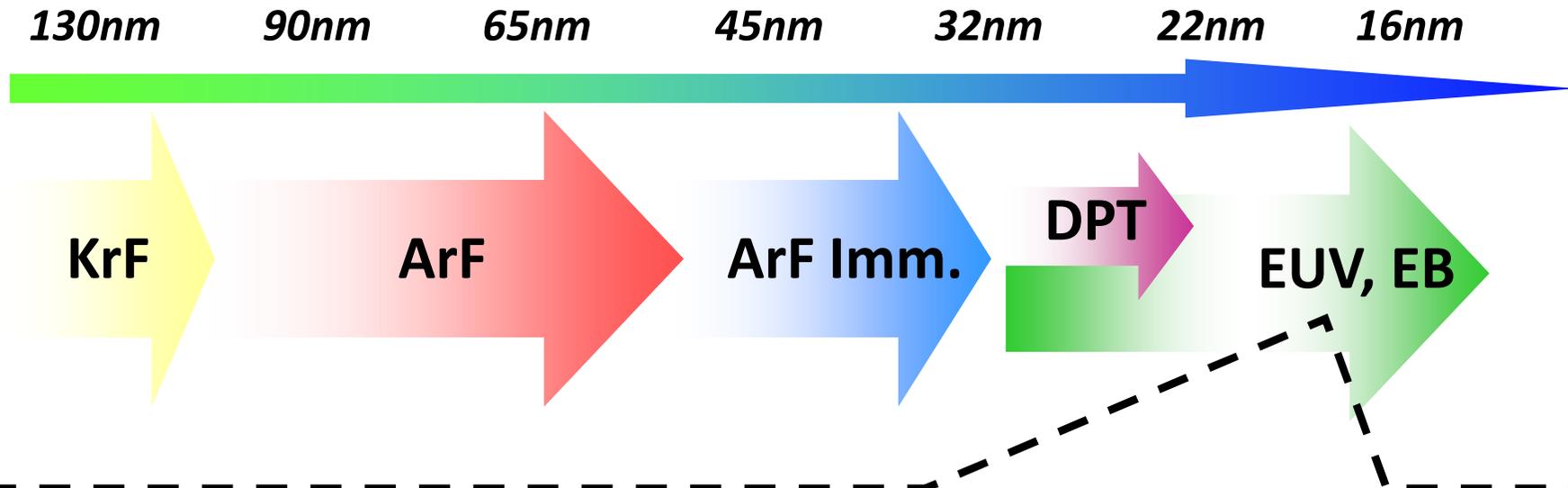
# High Resolution approach from EUV sensitive Si Hard Mask for 1X nm generation

O Wataru Shibayama, Ryuji Onishi, Noriaki Fujitani , Rikimaru Sakamoto,

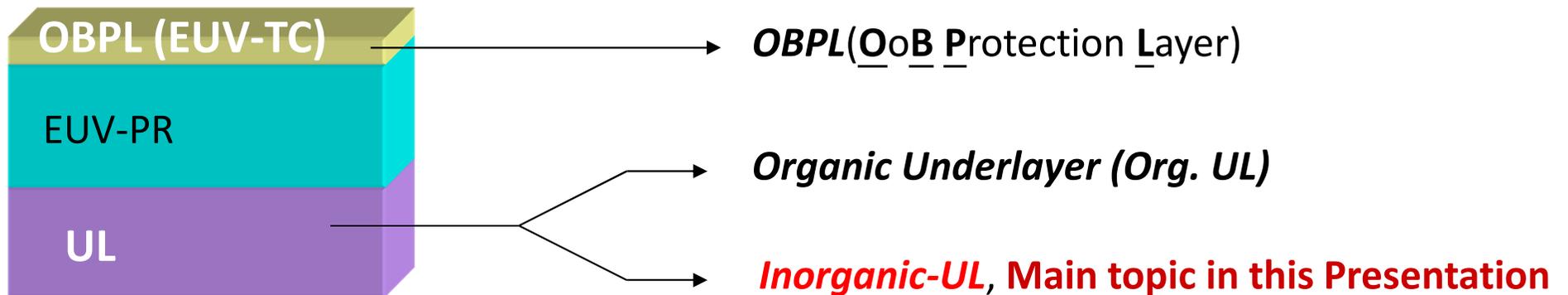
Nissan Chemical Industries, LTD  
Electronic Materials Research Lab.

- 1. Motivation**
- 2. Development of EUV Si-HM for hp20~23nm**
- 3. New challenge of EUV Si-HM for hp1X nm**
- 4. Summary**

## Lithography Technology



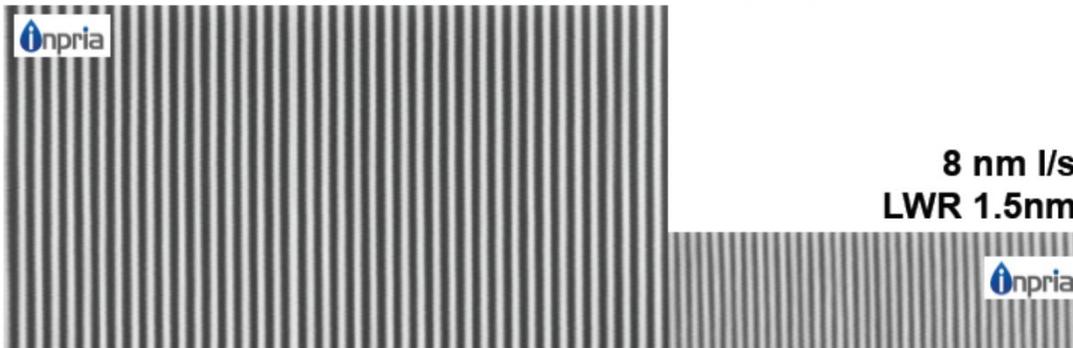
### • Nissan Chemical R&D Activity for EUVL



## Inorganic Materials for Advanced lithography



### Gen 1 Materials: EUV Imaging



*DDRP & DDRM for Novel free collapse process*

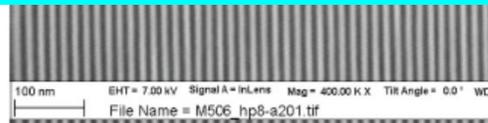
Rikimaru Sakamoto, Nissan Chemical

*SPIE advanced lithography 2013*

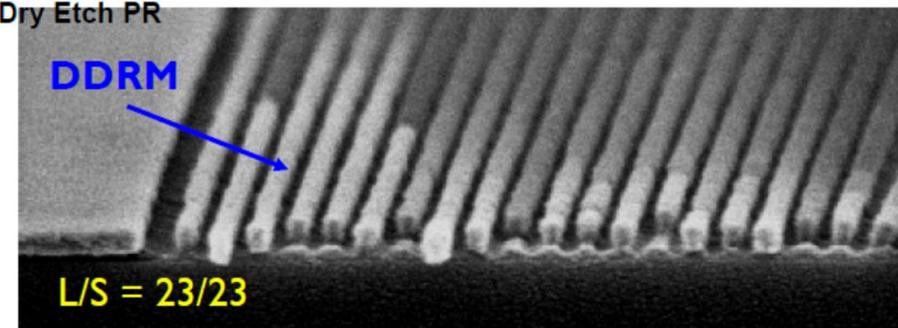
***Inorganic materials have much potential to break the common theory***



100 nm EHT = 7.00 kV Signal = InLens File Name = M506  
10 nm l/s  
LWR 0.7 nm



Post Dry Etch PR



*Advances in Directly Patternable*

*Metal Oxides for EUV Resist*

Andrew Grenville, Inpria

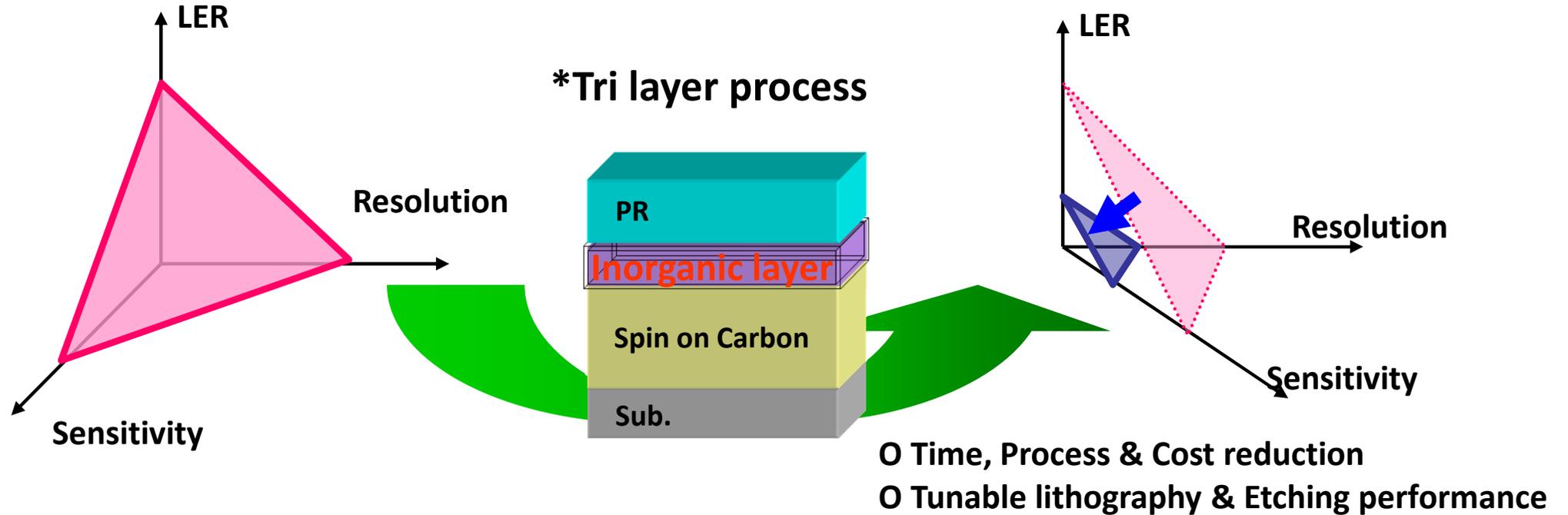
*EUVL Symposium 2013*

*NISSAN CHEMICAL INDUSTRIES, LTD.*

**Dry development patterning was successfully obtained without collapsing and bridging.**

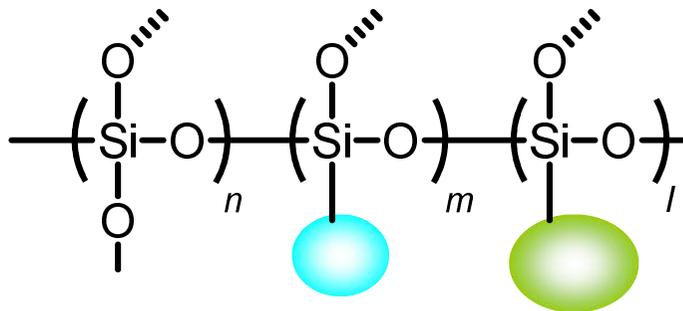
## RLS trade-off & Si containing Hard Mask

Exceed the RLS limit of Photo-resist by Applying functional **Inorganic Layer**.



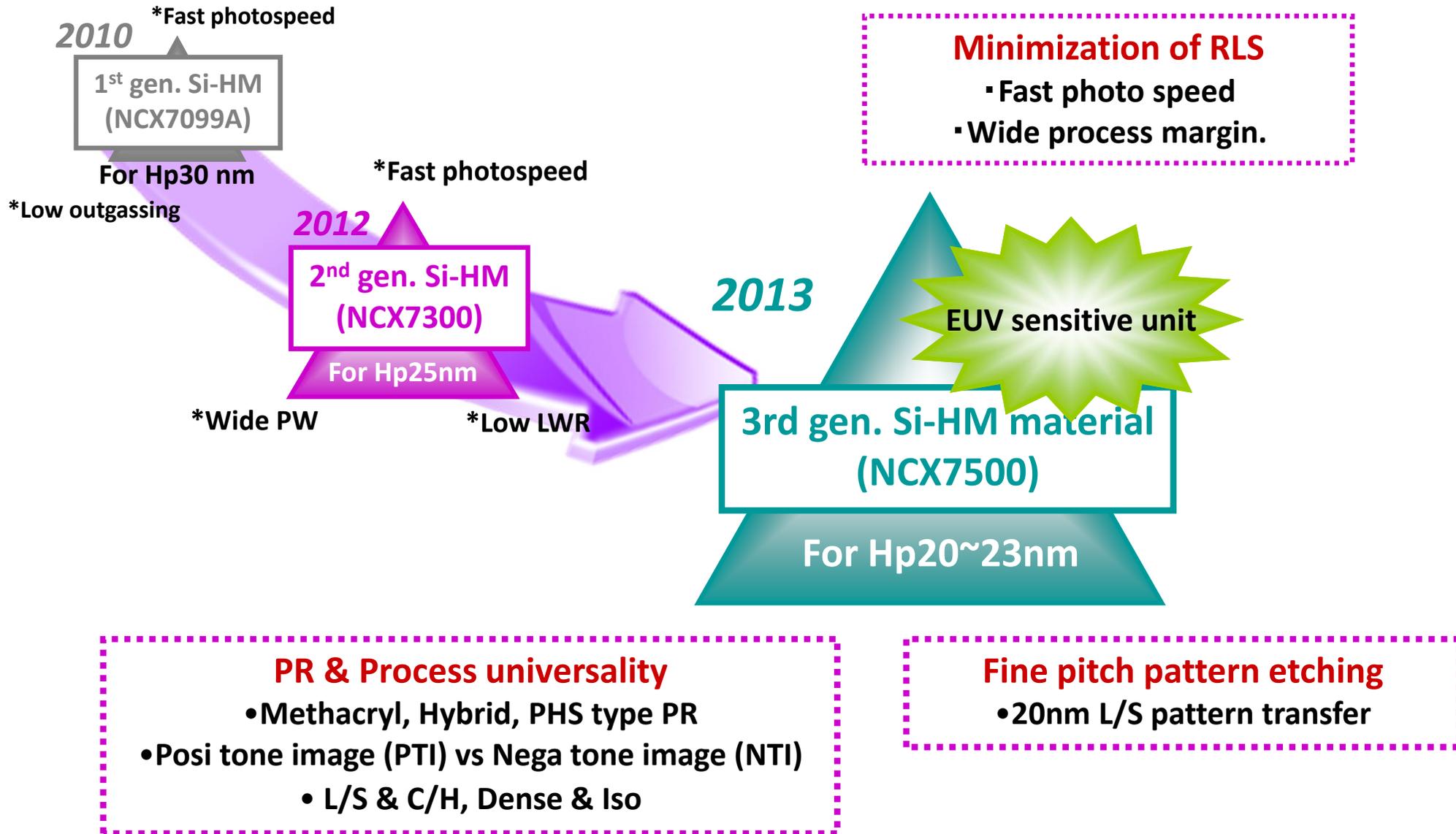
### Si containing Hard Mask (Si-HM)

FTK : 30-10nm



- Lithography enhancement layer
- Etching hard mask

## Road map for Nissan Si-HM for EUVL

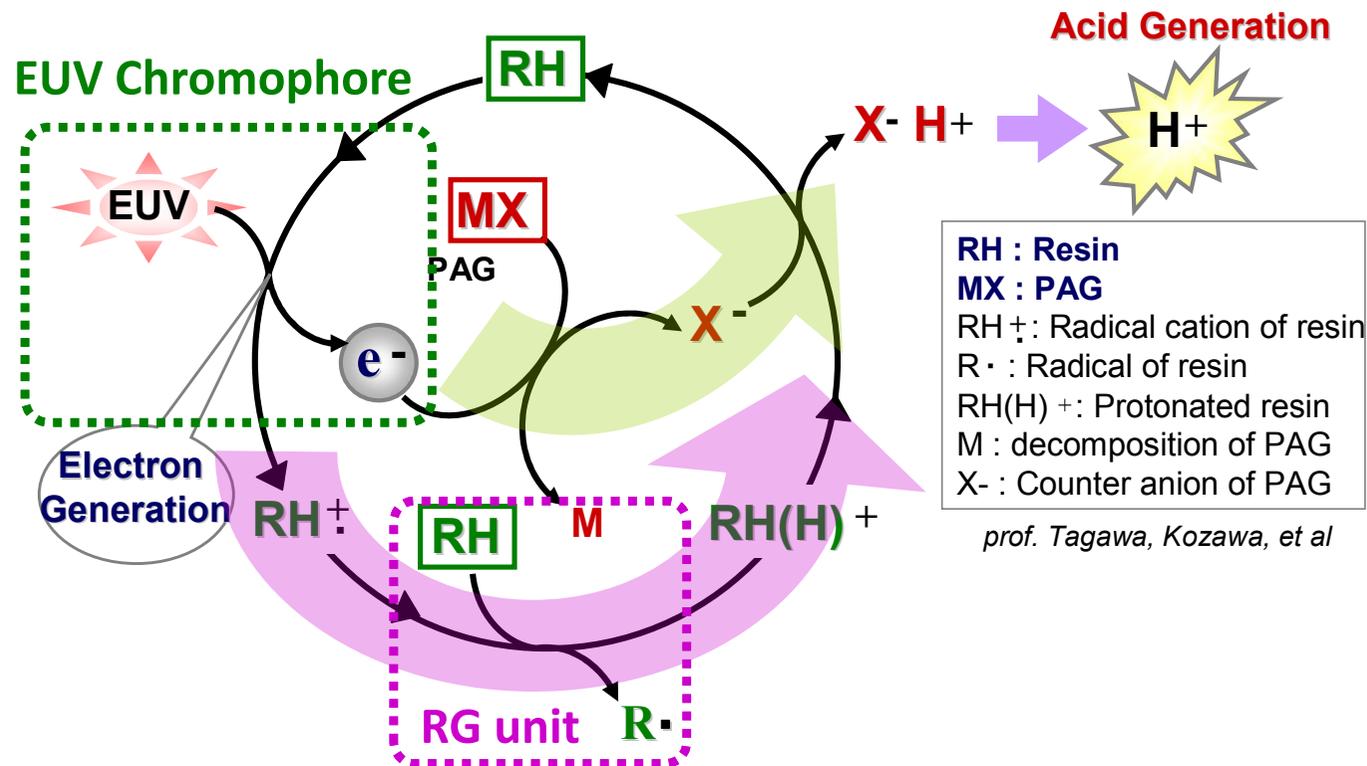


## Photo-speed enhancement

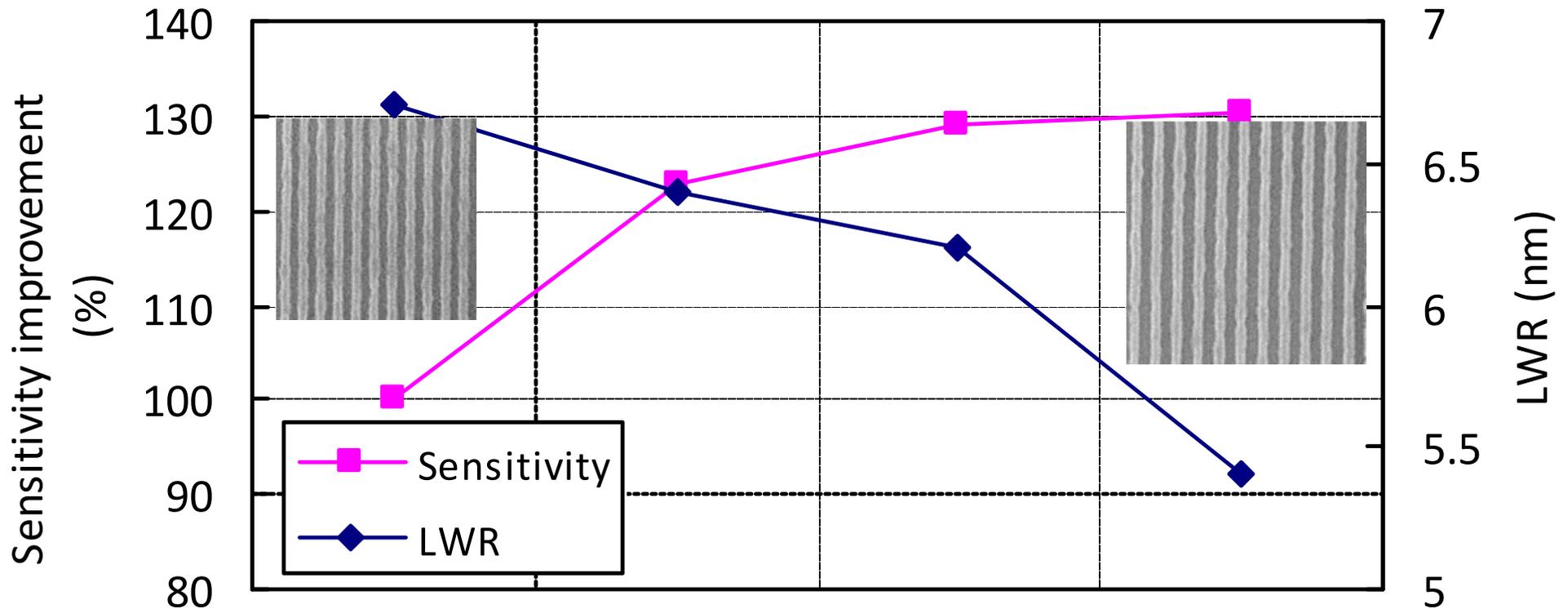
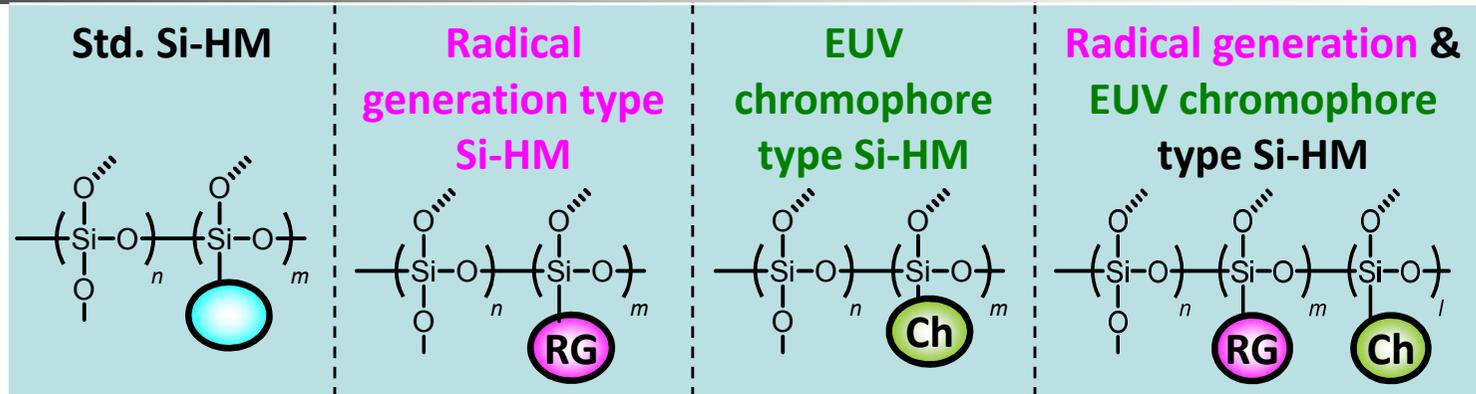
EUV sensitive unit  $\left\{ \begin{array}{l} \text{Radical generation unit} \\ \text{EUV chromophore} \end{array} \right.$

(High EUV absorption unit : Halogen, Hetero atom)

\*The mechanism of acid generation by EUV



# Photo-speed & LWR improvement



**High acid generation from Si-HM is key point to break the RLS trade-off**

*NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.*

# EUV lithography results @ Hp22nm L/S



Stack	Std. Organic UL	3 <sup>rd</sup> gen. EUV Si-HM (NCX7500)
UL structure		$\text{---}(\text{Si-O})_n\text{---}(\text{Si-O})_m\text{---}(\text{Si-O})_l\text{---}$
Dose to size, mJ	12.81	11.74 (+10%)
LER, nm	3.72 (+7%)	3.99
DOF at 10% EL, um	0.26	0.28 (+8%)
Max EL, %	20.12	22.54 (+12%)
Ultimate resolution, nm	Hp20nm	Hp19nm (+5%)
Top view		
X-SEM		

**NCX7500 can exceed in sensitivity, process window & resolution compared to PR own property.**

## EUV lithography results @ 26nm C/H



Stack	Std. Organic UL	3 <sup>rd</sup> Gen. EUV Si-HM (NCX7500)
UL structure		
Dose to size, mJ	20.98	<b>19.98 (+5%)</b>
1 sigma LCDU	<b>1.20 (+20%)</b>	1.50
Average CER (3 sigma nm)	<b>1.38 (+8%)</b>	1.50
Max DOF, um	<b>0.30</b>	<b>0.30</b>
Max EL, %	13.30	<b>16.57 (+25%)</b>
Ultimate Resolution, nm	<b>24nm</b>	<b>24nm</b>
Top view		
X-SEM		

NCX7500 also showed high universality in dense L/S & C/H.

## EUV lithography results @ 24nm L/S in NTI process



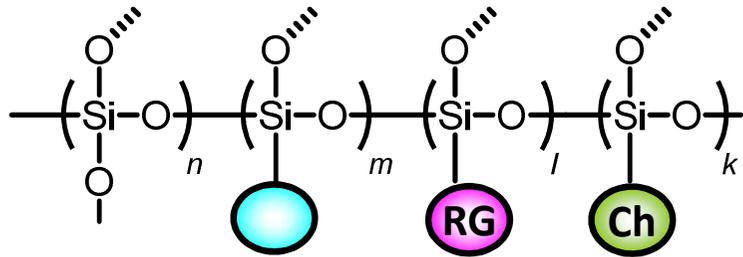
Stack	Nissan Organic UL (for NTI)	3 <sup>rd</sup> Gen. EUV Si-HM (NCX7500)
UL structure		
CD, nm	24.5	24.2
Dose, mJ	21.0	22.0
LWR, nm	4.6	3.9 (+15%)
DOF, nm	150	150
10 %EL, %	16.8	20.6 (+23%)
Ultimate Resolution, nm	Hp22nm	Hp22nm
Top view		
X-SEM		

**NCX7500 also showed good performance in NTI**

# 3<sup>rd</sup> Gen. EUV Si-HM for Hp20-23nm

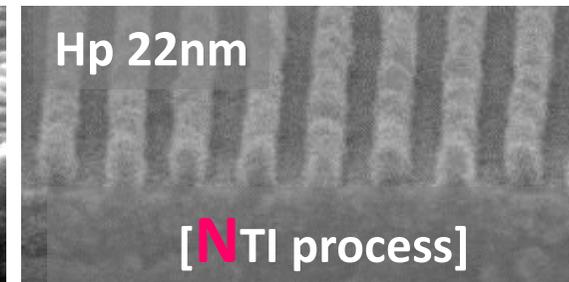
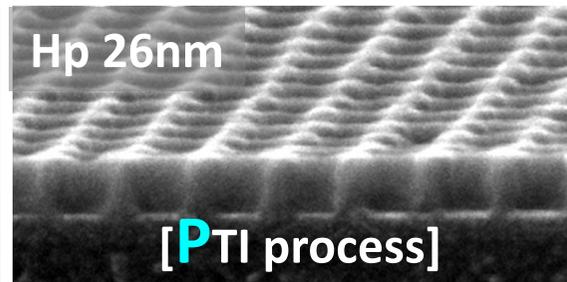
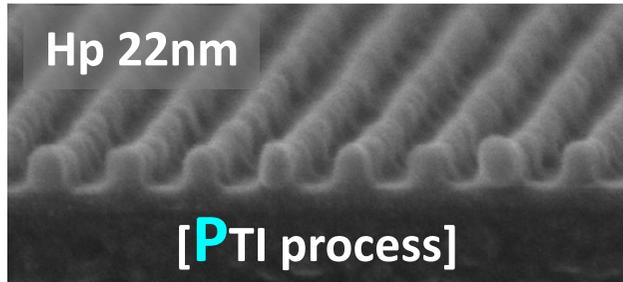
## NCX7500

\*Base polymer



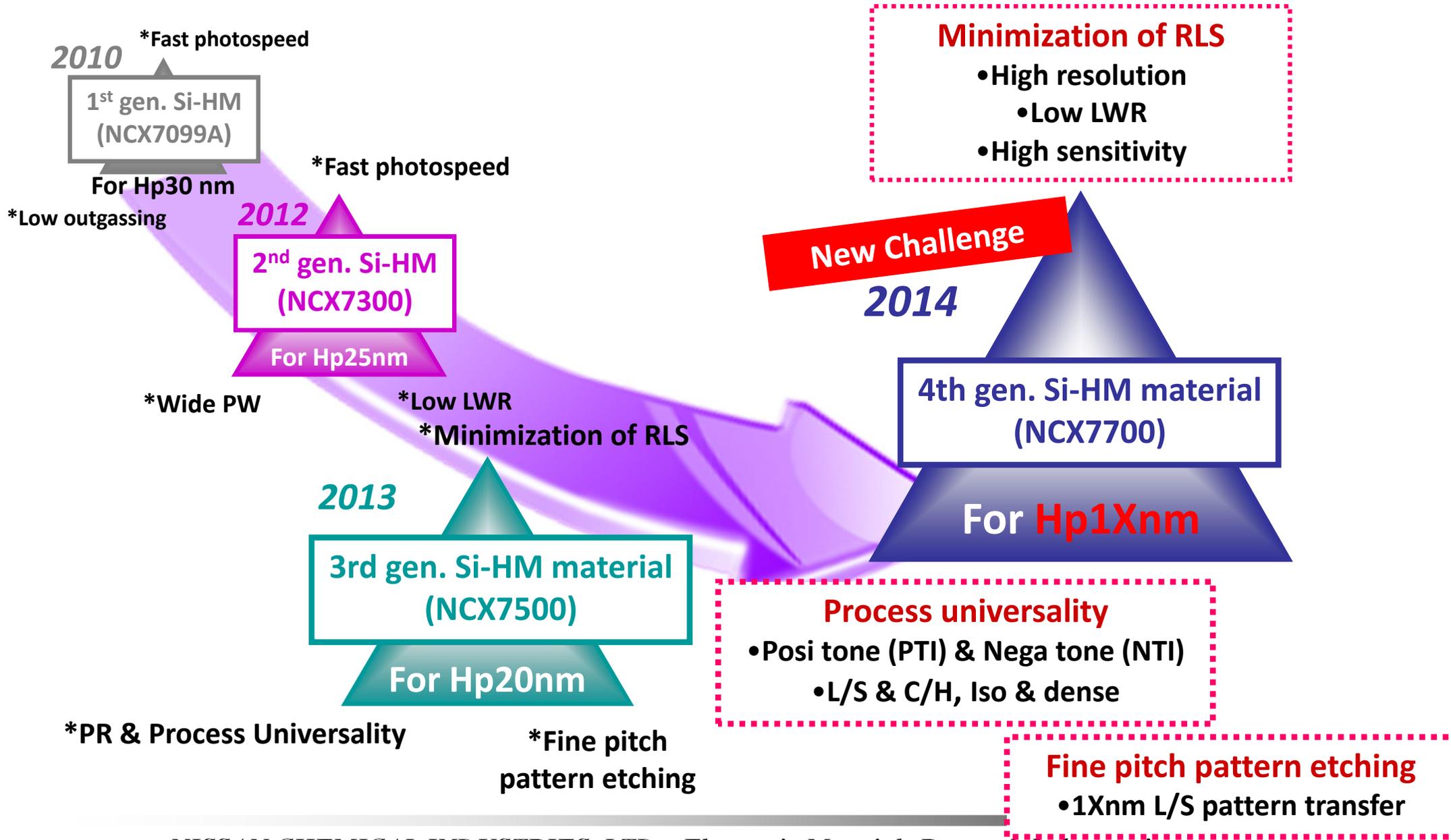
Radical generation & EUV chromophore

- High sensitivity, low LWR & wide PW in PTI
- High sensitivity, wide PW & High resolution in NTI

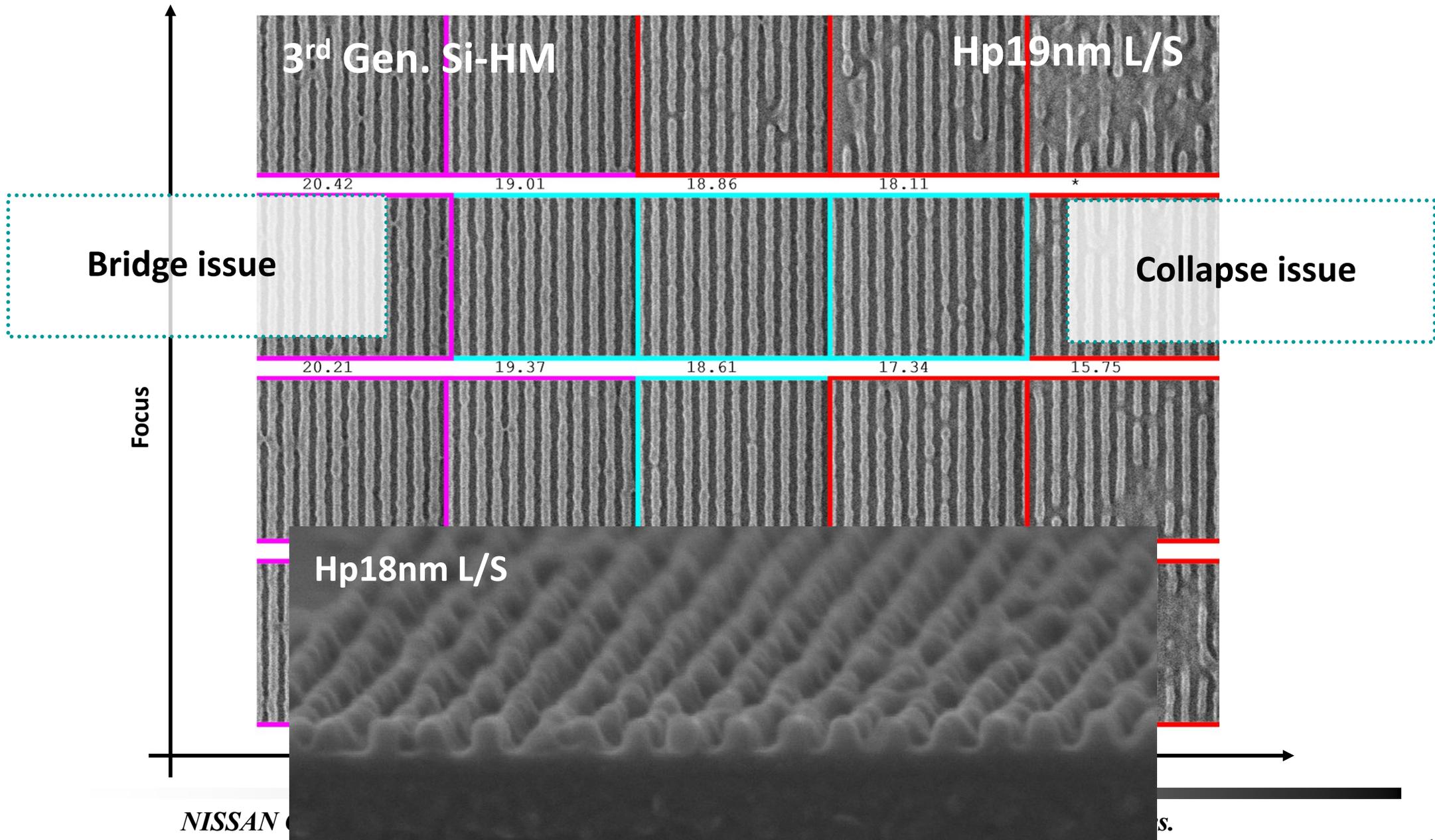


NCX7500 has high universality for PTI & NTI  
with any PR around hp 22nm

## New Road map for Nissan Si-HM for EUVL



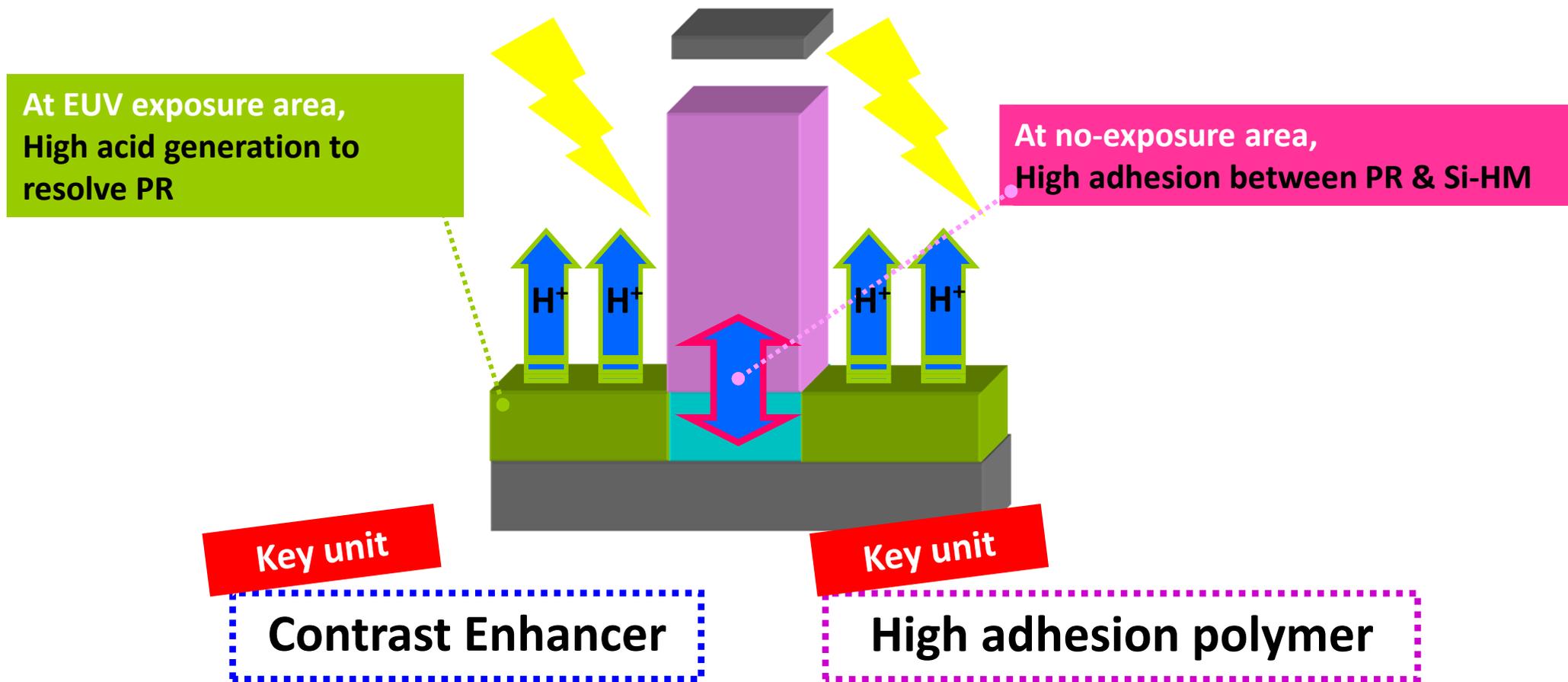
# EUV lithography results @ Hp1Xnm L/S



## High Resolution approach for hp1Xnm

To exceed PR limitation for 1Xnm,

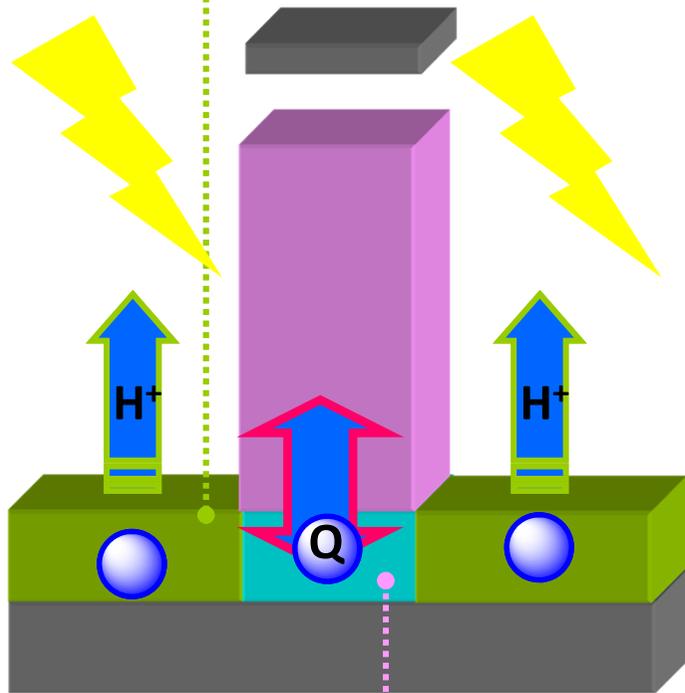
It is necessary to “enhance the contrast from Si-HM”



# High resolution concept 1 : Contrast Enhancer



At EUV exposure area,  
Contrast Enhancer promote  
acid generation to resolve PR



At no-exposure area,  
Contrast Enhancer work as Quencher  
to prevent pattern collapse

SPIE 2013

[EUV-sensitive Si containing Hard Mask (Si-HM) for  
PTD and NTD process in EUVL ]

Wataru Shibayama, Nissan Chemical



## Contrast Enhancer ~Process window~



Tool : MET (Micro Exposure Tool)  
Condition : Quadropole (0.68/0.36)  
PR : Std. PR

Hp 26nm

1 <sup>st</sup> gen. Std. Si-HM	Contrast Enhancer (A) Acid assist : Weak	Contrast Enhancer (B) Acid assist : Middle	Contrast Enhancer (C) Acid assist : Strong
Good shot : 6	Good shot : 7	Good shot : 8	Good shot : <b>11</b>
LWR : 6.0nm	LWR : 5.6nm	LWR : 5.5nm	LWR : <b>5.3nm</b>

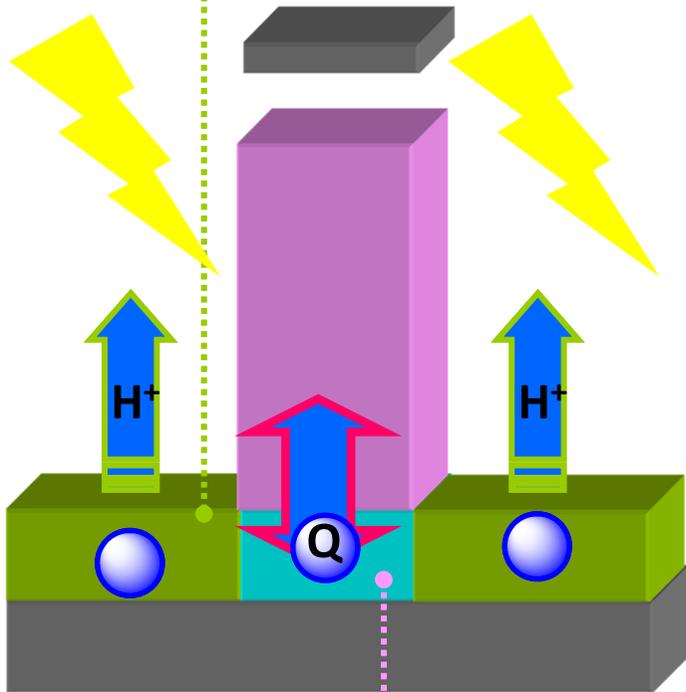
**Contrast Enhancer can not only enhance the process window,  
but also control PR profile.**

NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.

# High resolution concept 1 : Contrast Enhancer



At EUV exposure area,  
 Contrast Enhancer promote  
 acid generation to resolve PR

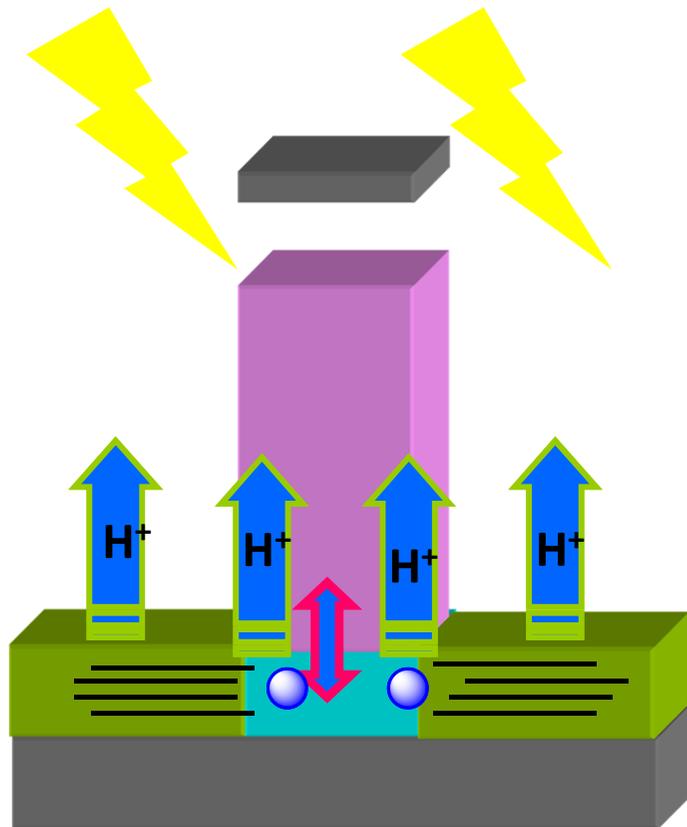


At no-exposure area,  
 Contrast Enhancer work as Quencher  
 to prevent pattern collapse

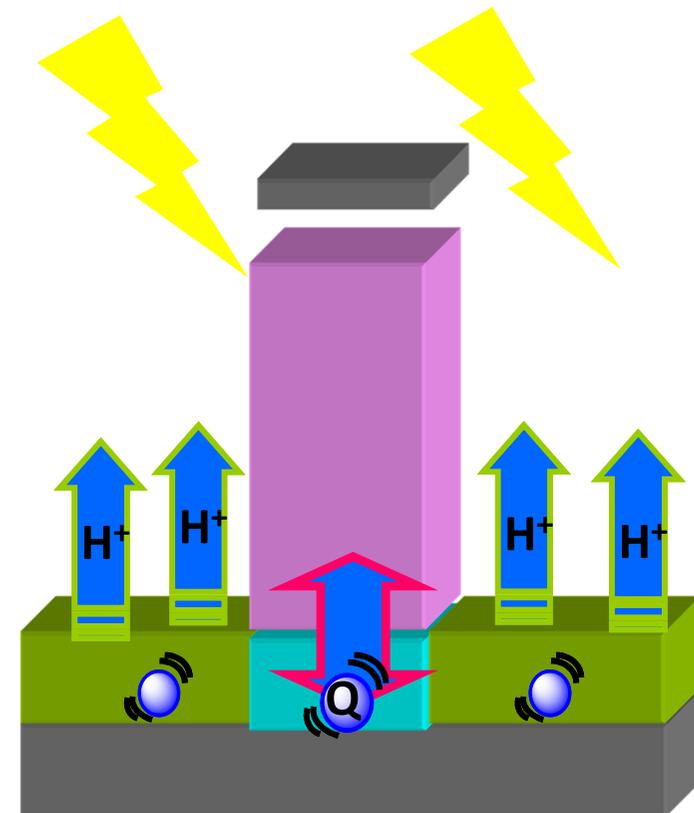
Contrast Enhancer A	Contrast Enhancer B
Diffusion : High	Diffusion : Low
Min. CD:19.6nm Max. CD:26.8nm	Min. CD:16.3nm Max. CD:26.2nm

## Contrast Enhancer effect

### High diffusion type Contrast Enhancer



### Low diffusion type Contrast Enhancer

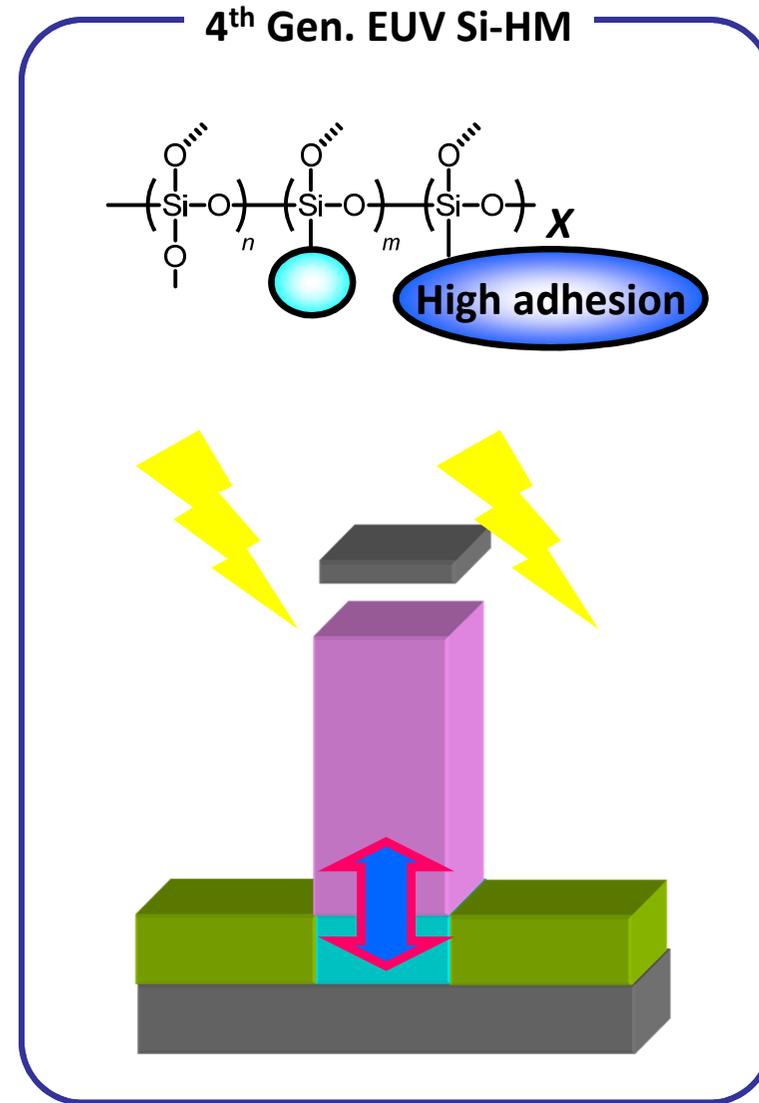
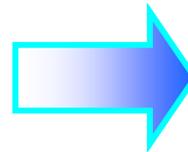
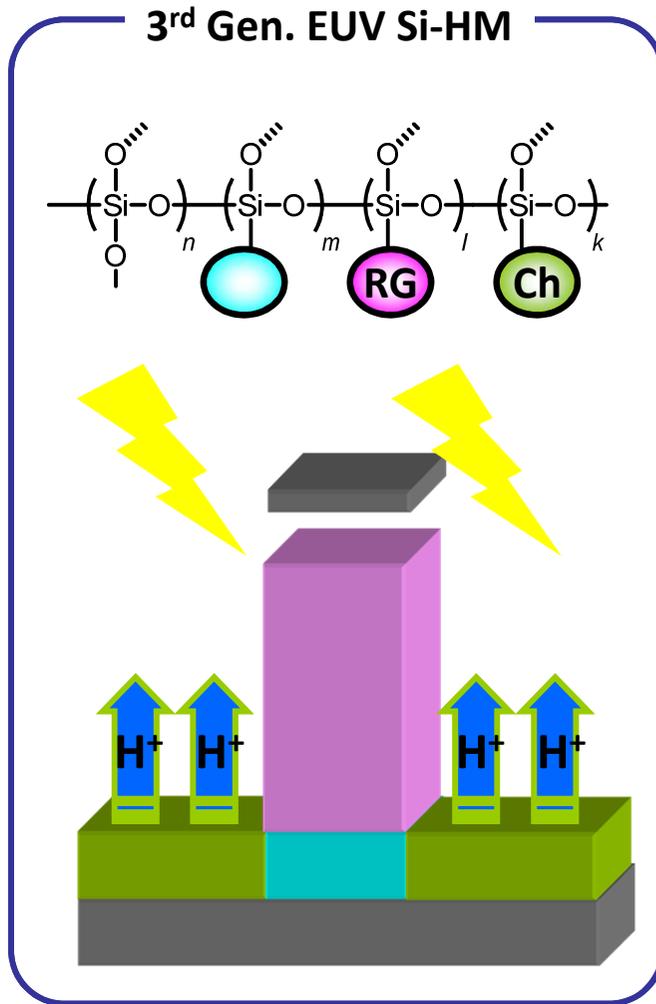


**Low diffusion type Contrast Enhancer is effective !!!**

## High resolution concept 2 : High adhesion unit

Key unit

### High adhesion polymer

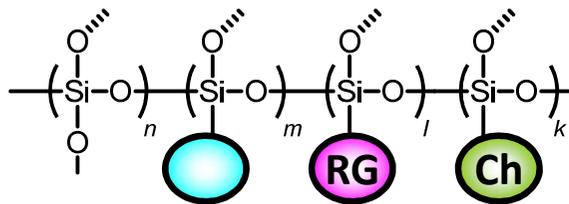
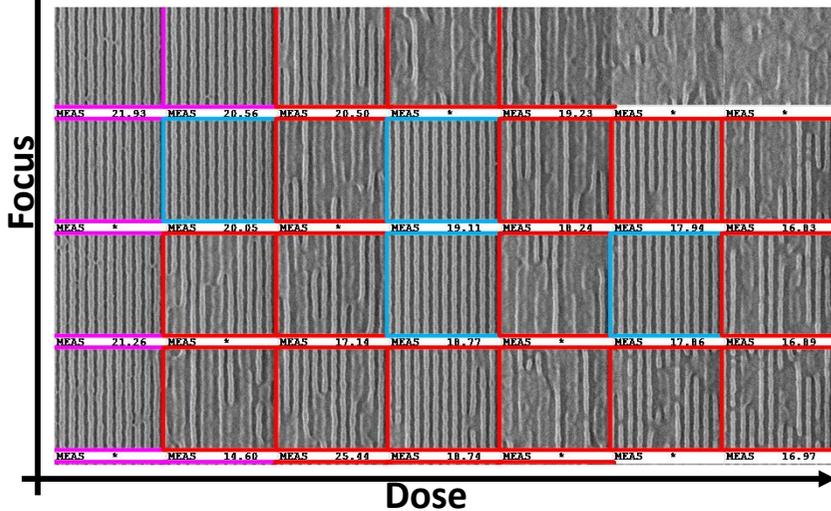


## Process window (Hp19nm L/S)

### 3<sup>rd</sup> Gen. EUV Si-HM

Min. CD : 17.9nm

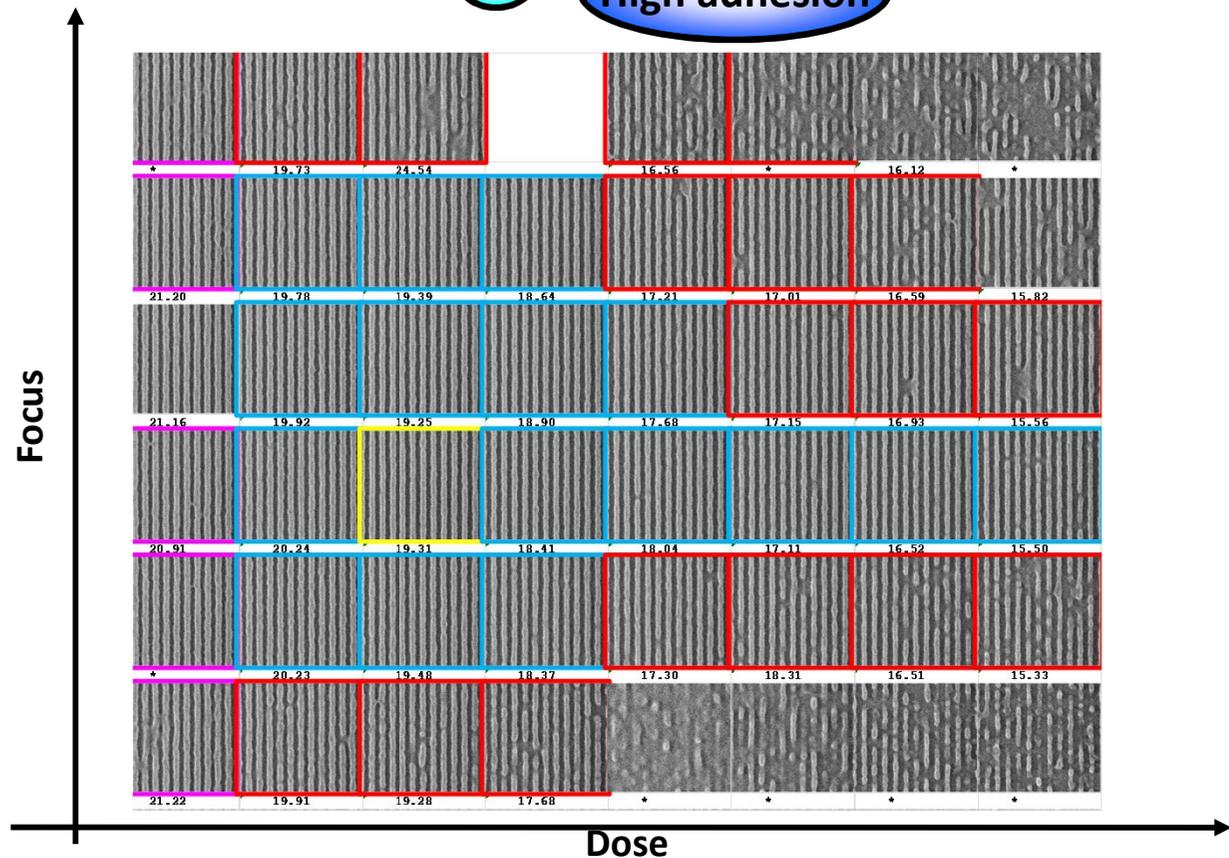
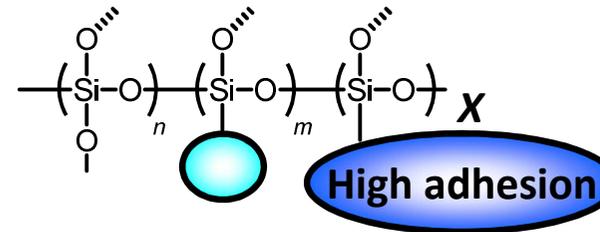
DOF : 0.05um



### 4<sup>th</sup> Gen. EUV Si-HM

Min. CD : 15.5nm

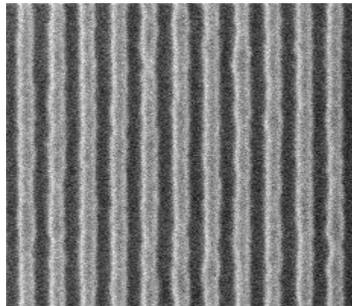
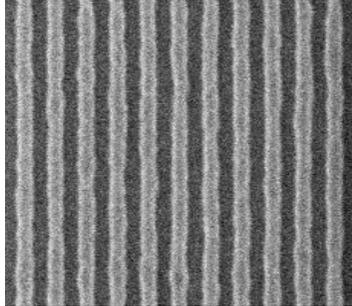
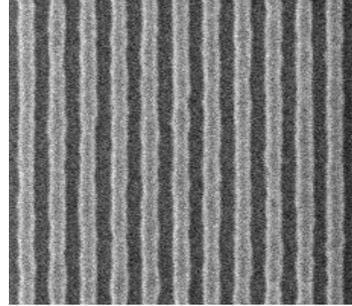
DOF : 0.15um



In over dose area, 4<sup>th</sup> Gen. Si-HM can prevent pattern collapse

# EUV lithography results (Hp20nm L/S)



Stack	Org. UL	3 <sup>rd</sup> gen. Si-HM (NCX7500)	4 <sup>th</sup> Gen. EUV Si-HM (NCX7700)
20nm hp			
Resolution, nm	Hp20nm	Hp19nm	Hp18nm
Dose to size, mJ	18.01	15.94 (+13%)	16.57 (+9%)
LER, nm	3.51	3.63 (+3%)	3.51
DOF at 10% EL (um)	0.160	0.198 (+24%)	0.198 (+24%)
Max EL, %	0.225	>0.220	> 0.250 (+11%)
Rank	3rd	2nd	1st

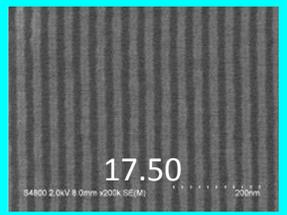
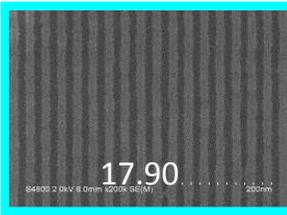
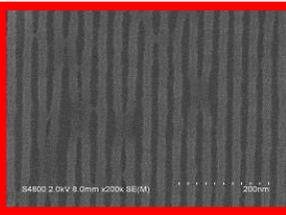
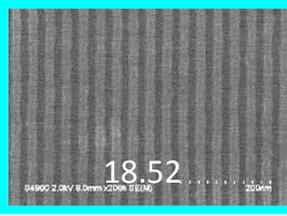
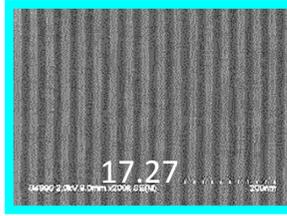
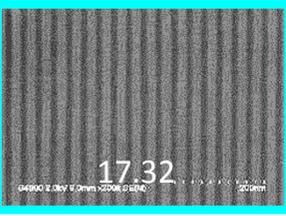
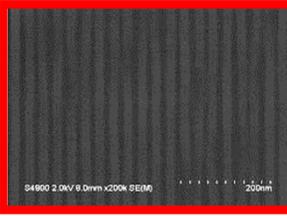
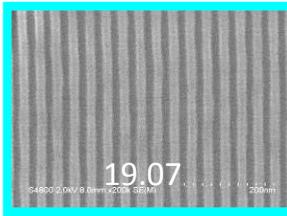
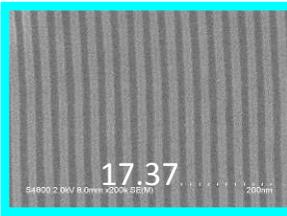
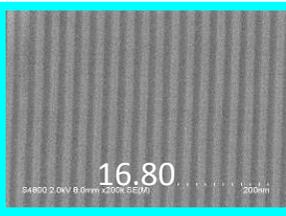
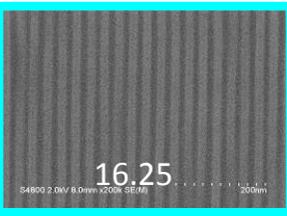
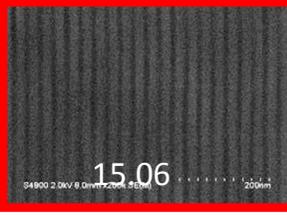
**4<sup>th</sup> Gen. EUV Si-HM have higher performance**

# Resolution (Hp1Xnm L/S)



Illumination : Pseudo PSM

**NEXL**<sup>TM</sup>  
Challenging and Solution by x-layer

	Hp19nm	Hp18nm	Hp17nm	Hp16nm	Hp15nm
NCX7500 (3rd gen. Si-HM)					
NCX7700 (4 <sup>th</sup> Gen. Si-HM)					
New Si-HM NCX7800 (4 <sup>th</sup> Gen. Si-HM)					

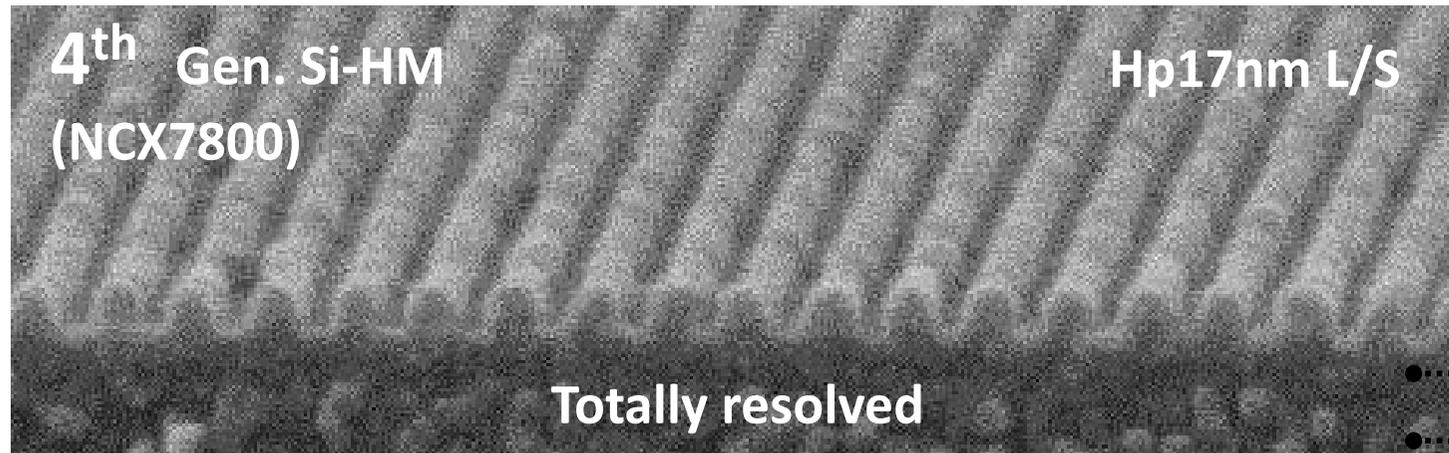
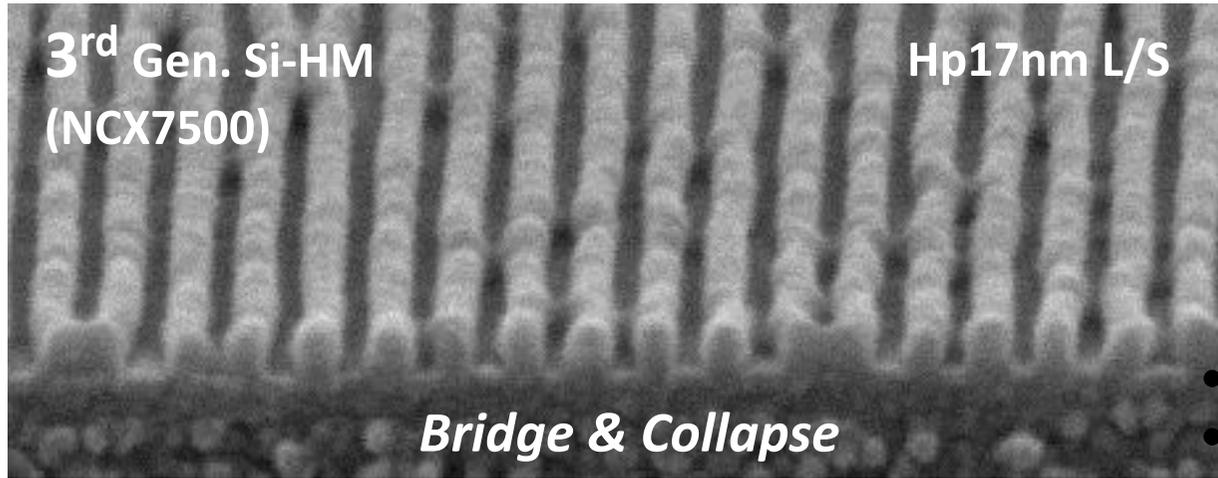
**NCX7800 have reached to Hp16nm resolution.**

# Resolution (Hp17nm L/S)



Illumination : Pseudo PSM

**NEXL**<sup>TM</sup>  
Challenging and Solution by x-layer



**4<sup>th</sup> Gen. EUV Si-HM can enhance the resolution to hp18nm L/S**

*NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.*

## Etching demonstration

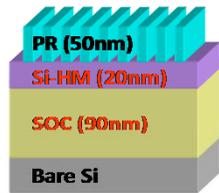
Etching demonstration ~Hp30nm dense L/S~



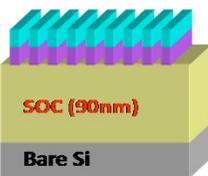
SPIE 2013

[EUV-sensitive Si containing Hard Mask (Si-HM) for PTD and NTD process in EUVL]  
Wataru Shibayama, Nissan Chemical

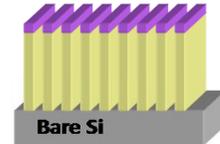
L/S : 30nm / 30nm



Litho

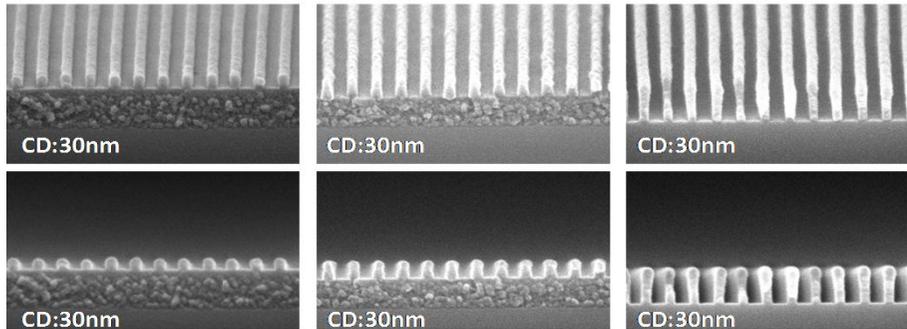


Si-HM open



SOC open

Si-HM open : CF<sub>4</sub> and others  
SOC open : O<sub>2</sub> and others



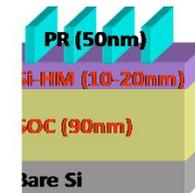
Our EUV Si-HM have enough etching resistance at fine pitch.

Hp 19nm dense L/S  
Pattern etching

Etching demonstration ~20nm Semi iso Line~



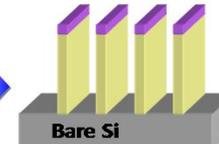
L/S : 20nm / 130nm



Litho

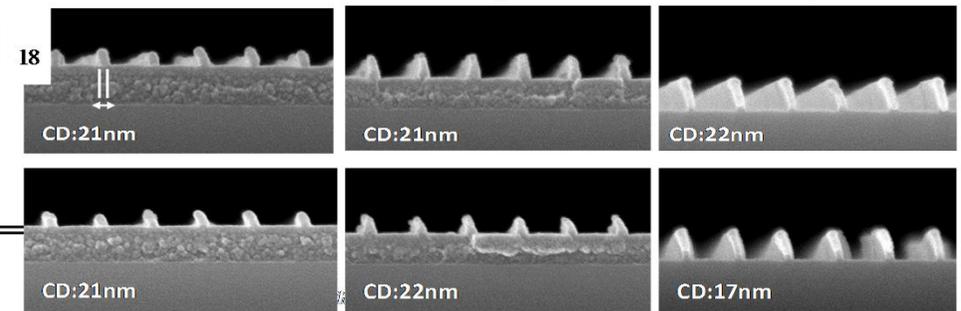


Si-HM Open



SOC Open

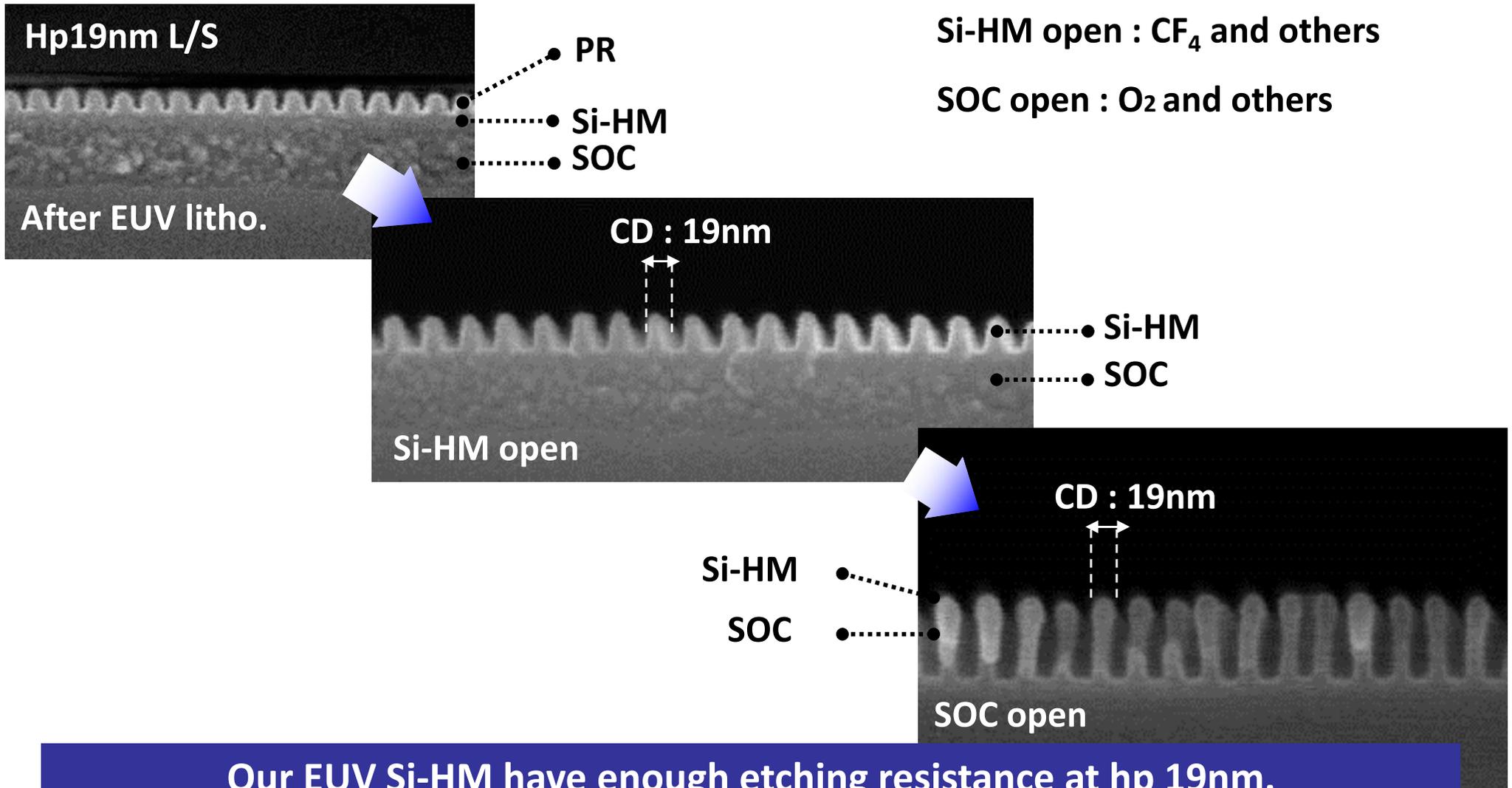
Si-HM open : CF<sub>4</sub> and others  
SOC open : O<sub>2</sub> and others



Si-HM FTK : 10nm

Our EUV Si-HM have enough etching selectivity even in 10nm FTK at 20nm line

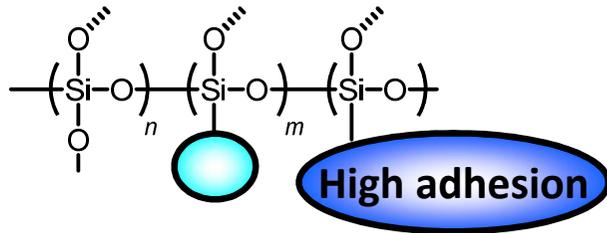
## Etching demonstration ~Hp19nm dense L/S~



# New Nissan 4<sup>th</sup> Gen. EUV Si-HM for 1Xnm : NCX7800

## NCX7800

\*Base polymer



High adhesion unit

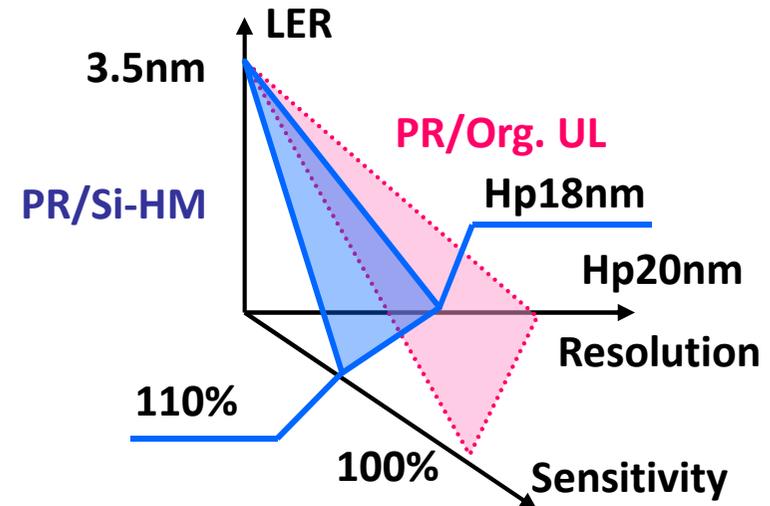
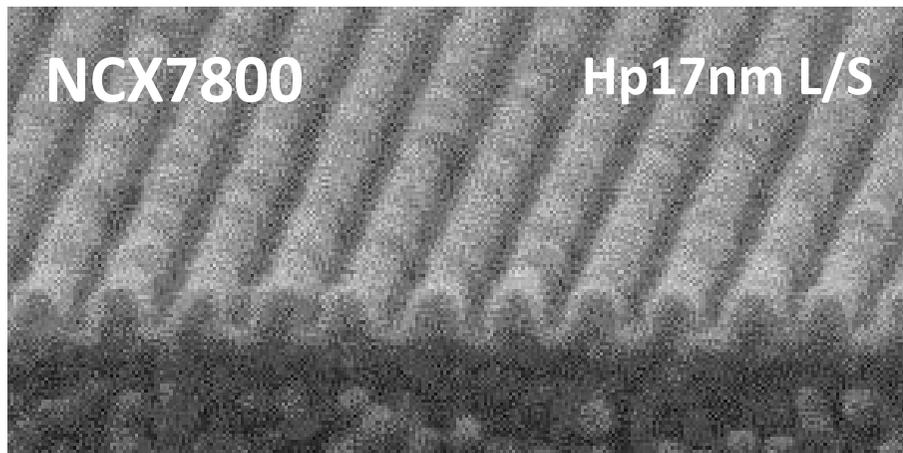
- High adhesion with PR

\*Special Additives



Contrast Enhancer (Low diffusion type)

- Wide process margin
- Low LWR



Exceed the limit of Photo resist by applying high contrast concept

## Summary

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- **3<sup>rd</sup> Gen. Si-HM with EUV sensitive unit (NCX7500) has been developed for hp20-24nm.**
- **Radical generation unit, EUV chromophore can improve  
sensitivity, LWR and Process window**
- **For Hp 1Xnm, We newly started to develop high resolution type Si-HM.**
- **The key unit for hp1Xnm resolution is high polaritic unit & Contrast Enhancer.**
- **4<sup>th</sup> Gen. EUV Si-HM (NCX7800) can achieve hp16nm resolution & minimize RLS trade-off.**

# Acknowledgement

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**Thank you for kind attention**