NEXL™
Challenging and Solution by x-layer

Novel Si-contained Inorganic Hard Mask (Si-HM) for around Hp 20nm

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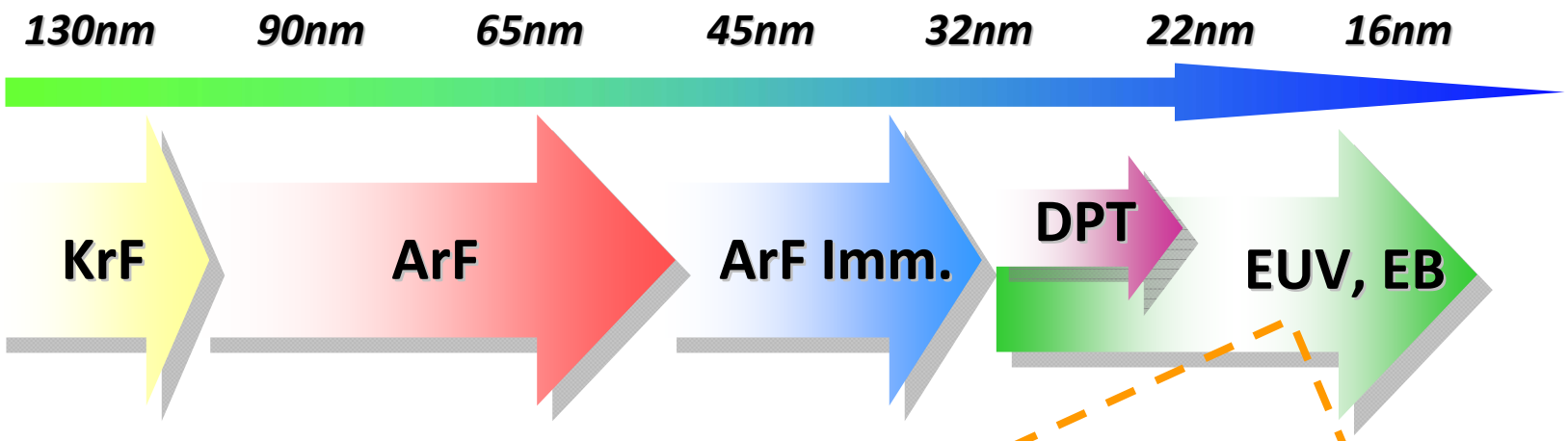
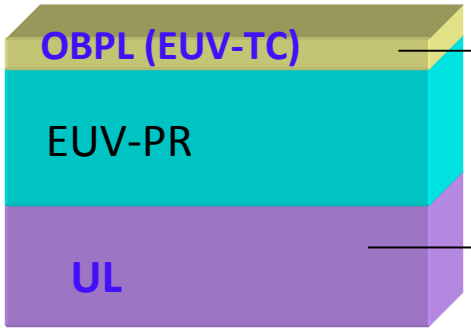
Introduction

•Lithography Technology



•NCI R&D Activity for EUVL



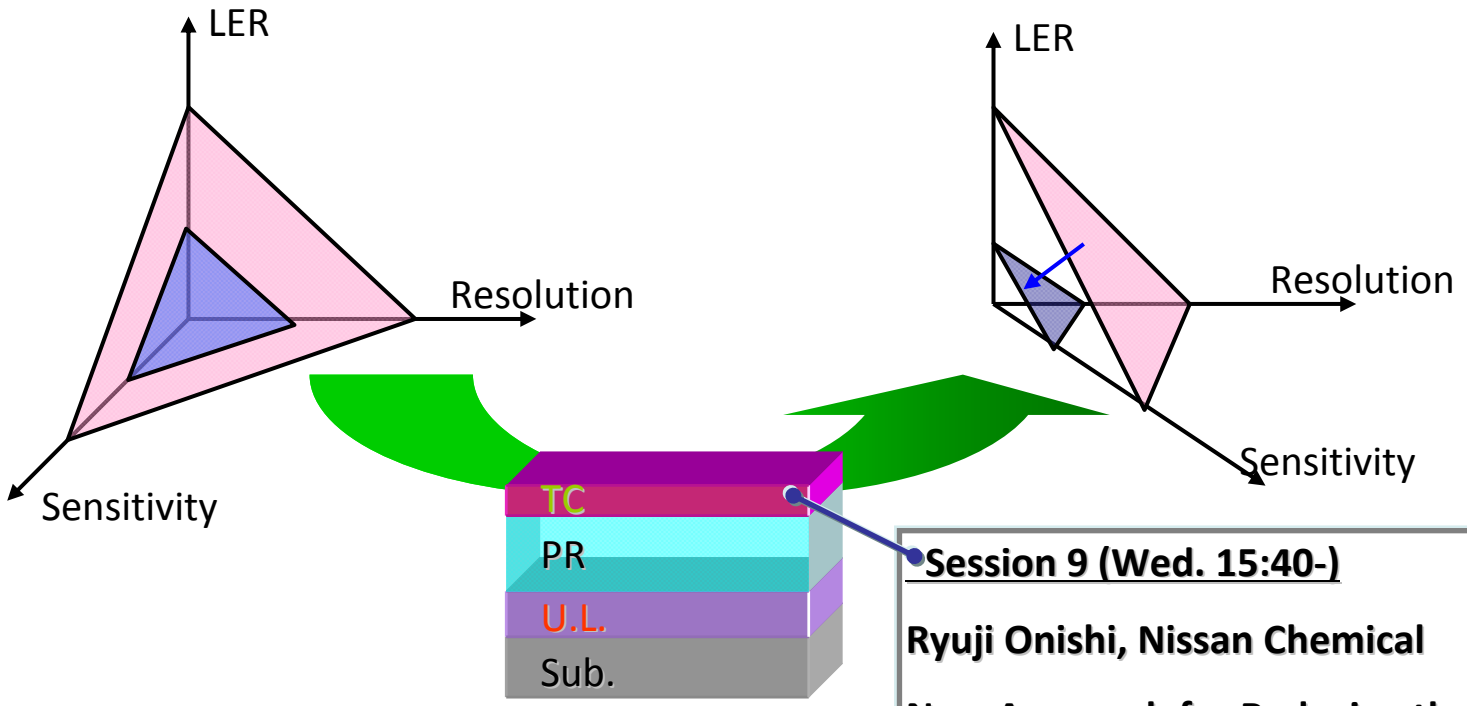
OBPL(OoB Protection Layer)

Org.-UL

Si-HM , **Main topic in this Presentation**

Introduction

RLS trade off



Session 9 (Wed. 15:40-)

Ryuji Onishi, Nissan Chemical

New Approach for Reducing the Out of Band Effect and Outgassing by applying Top Coat materials.

Help minimizing of RLS trade off by Applying functional Under Layer & Topcoat.

The requirement of Tri-layer materials

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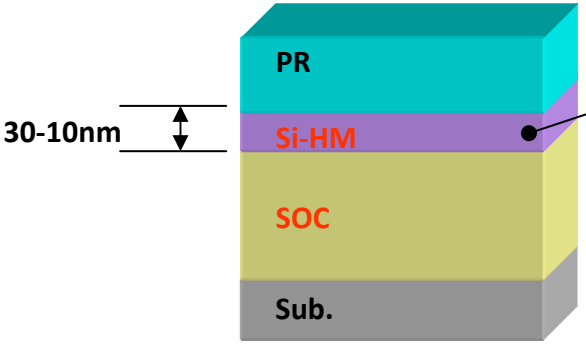
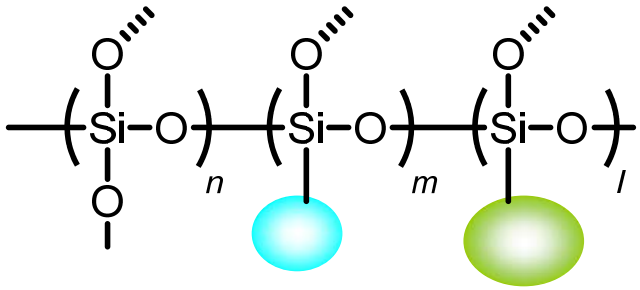


Inorganic (Si, Ti etc.) Hard Mask (Si-HM)



- Lithographic performance
- Etching performance
- Outgas performance

Development schedule of Nissan EUV Si-HM

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2012 Q1 Q2 Q3 Q4 2013 Q1

1ST gen. Si-HM
NCX7099A (for Hp>25nm)
- Fast photo-speed
- Wide process margin
- Good coating
- Low outgass

EUV symposium 2012

2nd gen. Si-HM
NCX7300
Target : Fast photo speed
For Hp < 24nm
Low LWR
Wide Process margin

3rd gen. Si-HM
NCX75XX
Target : For Hp < 22nm
PR universality

Nissan EUV Si-HM 1st gen. Sample : NCX7099A

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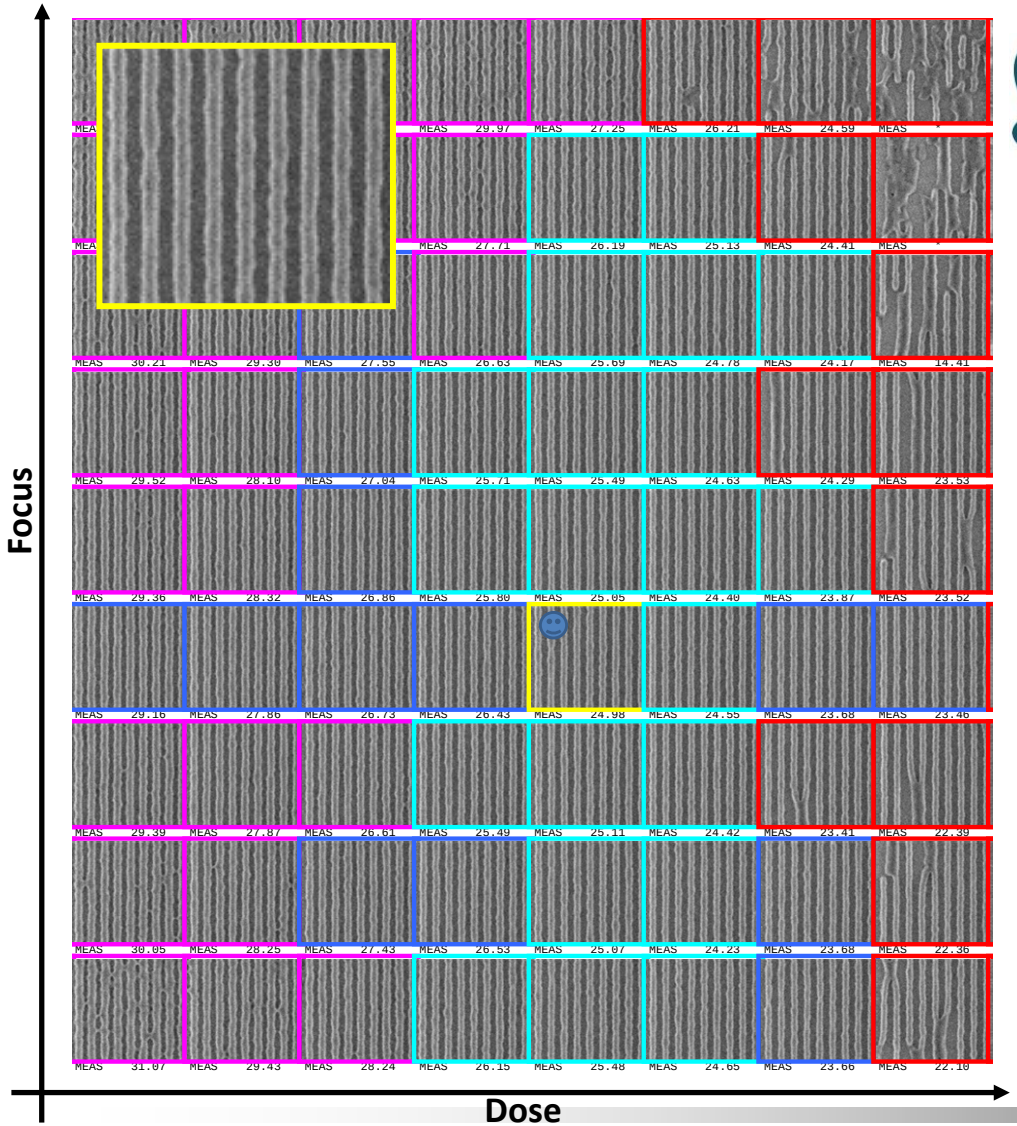


imec

Tool : NXE3100
Illumination : Dipole 60X (0.81/0.43)
NA : 0.25
PR : Std. PR

Eop **Within 5% CD** **Without 10% CD**

Scum Bridge **Collapse**

Hp 25nm

	NCX7099A	Org. UL (Nissan)
Dose to size (mJ/cm2)	**9.57**	10.96
CD(nm)	24.98	24.91
LER(nm)	4.41	**4.33**
DOF at 10% EL (um)	**0.20**	0.05
Max DOF (um)	**0.28**	0.20
Max EL (%)	**16.55**	11.74
Collapse limit (nm)	**23.46**	24.91

Total performances of Si-HM are beyond the Org. UL.

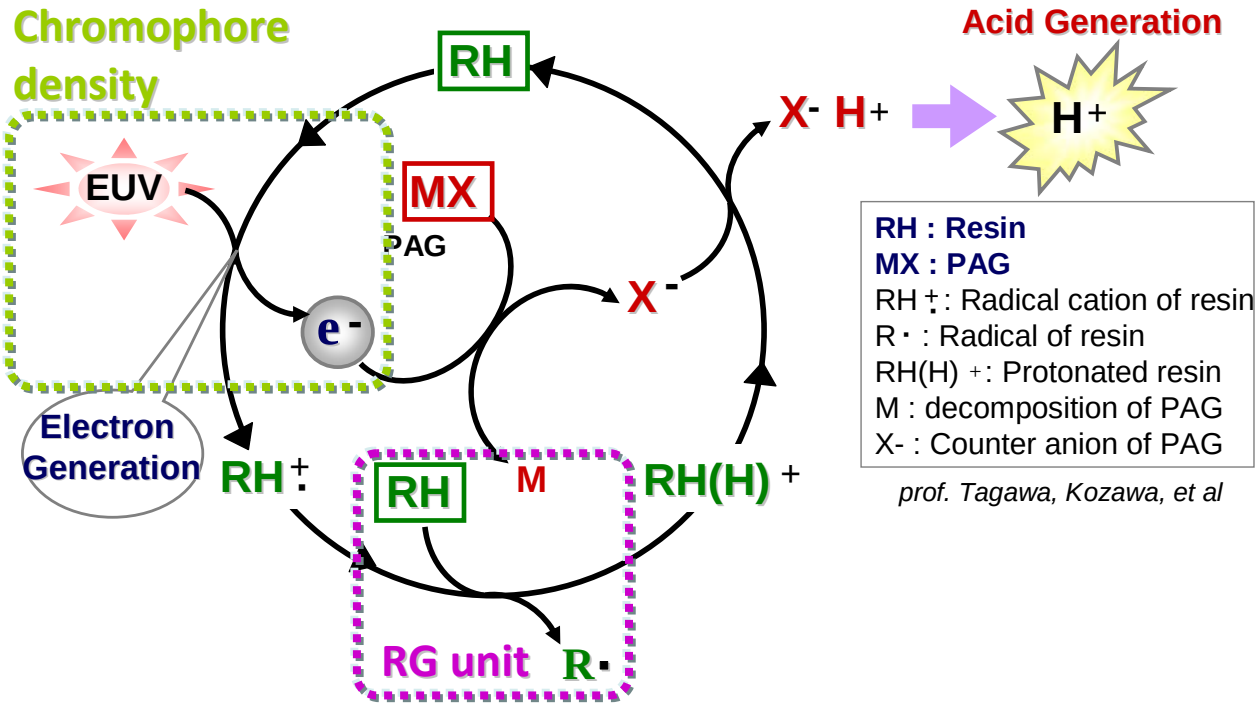
Lithographic Performance

Material Design for EUVL

2nd gen. Si-HM material

- **Photo-speed enhancement**
  - ・Chromophore Unit
  - ・Radical generation Unit
- **Resolution (from page 10)**
  - **Pattern Collapse Reduction**
    - ・X-link catalyst
  - **Wide process window**
    - ・high X-link polymer
- **LWR Improvement (from page 12)**
  - ・Contrast enhancer

Photo-speed enhancement



prof. Tagawa, Kozawa, et al

High sensitivity
- **Radical generation unit**
- **EUV chromophore (F, Cl, O, N atom)**

Photo-speed enhancement

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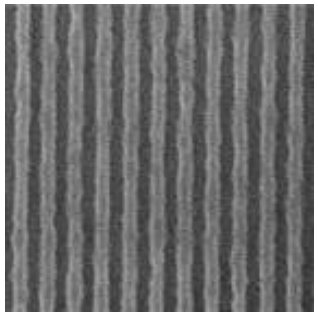
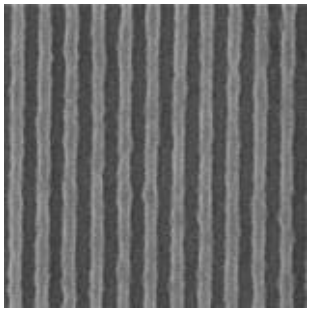
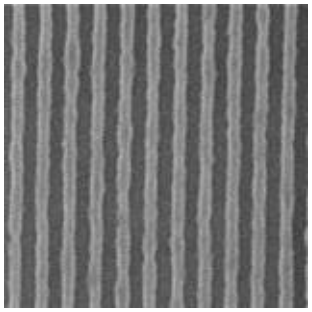
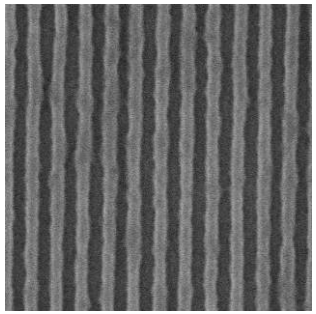
SEMATECH

Condition : Quadropole (0.68/0.36)
PR : Std. PR

Standard Si-HM	Radical generation type Si-HM	EUV chromophore type Si-HM	Radical generation & EUV chromophore type Si-HM
Eop: 13.0mJ LWR: 6.7nm CD: 28.7nm	Eop:10.58mJ LWR: 6.4nm CD: 30.0 nm	Eop: 10.08mJ LWR: 6.2nm CD: 29.2nm	Eop: **9.96mJ** LWR: **5.4nm** CD: 28.4nm

Sensitivity can be increased over 20% with keeping LWR.

Resolution ~ X-link catalyst~

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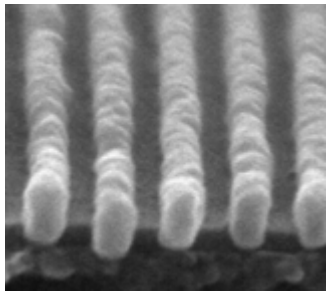
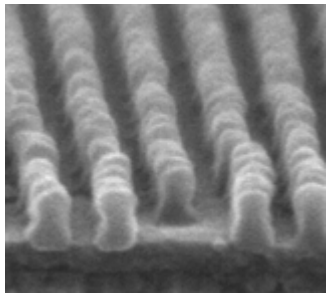
Data Courtesy of EIDEC

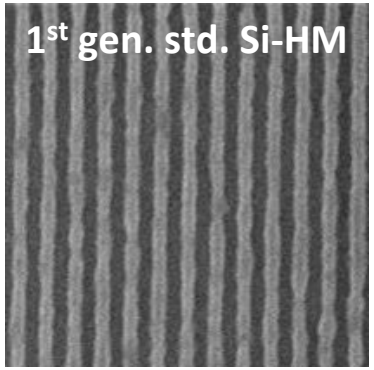
Tool : SFET (Small Field Exposure Tool)
Condition : Annular (0.3/0.7) NA=0.3
PR : ESR1

Si-HM sample		Weak cat. type 1st gen. Si-HM	Strong cat. type Si-HM
X-section SEM image		 Undercut	 footing
Resolution	nm hp	30	**26**
CD	nm	29.9	29.7
Max EL	%	13.4	**17.0**
LWR	nm	5.5	**4.9**
Sensitivity	mJ/cm^2	**14.6**	15.25

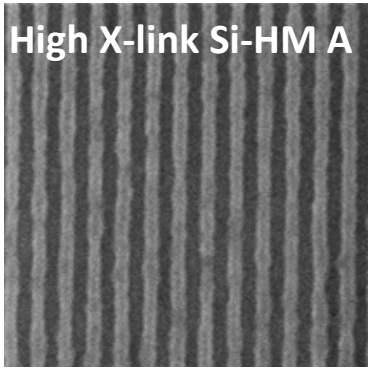
Resolution ~ High X-link polymer~

Tool : MET (Micro Exposure Tool)
Condition : Quadropole (0.93/0.36)
PR : Std. PR

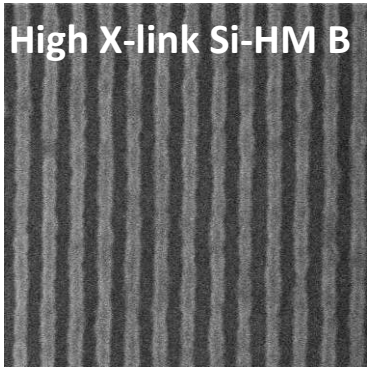
Sample (relative value)	Polymer	Fundamental data		
	High X link unit	Contact angle (DIW)	Density	Hardness
Standard Si-HM	100%			
High X-link Si-HM A	100%	110%	115%	140%
High X-link Si-HM B	110%	105%	115%	150%



Eop = 12.60 mJ
CD = 26.1 nm
LWR = 5.3 nm
DOF = 40 nm
EL = 8.2%



Eop = 12.85 mJ
CD = 25.9 nm
LWR = **4.9 nm**
DOF = 120 nm
EL = **11.7%**



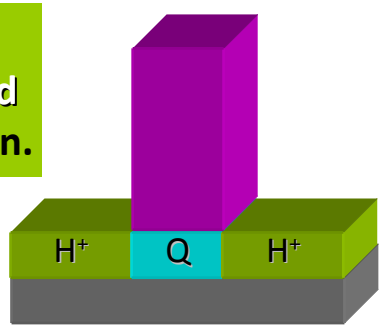
Eop = 12.60 mJ
CD = 25.5 nm
LWR = 5.3 nm
DOF = **160 nm**
EL = 9.3%

Contrast Enhancer

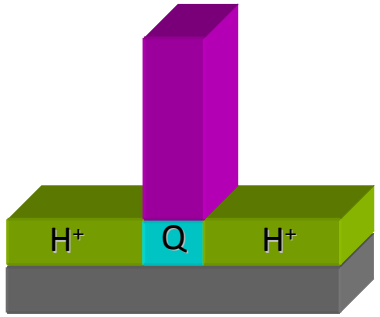
We newly developed Contrast Enhancer additives…

At no-exposure area,
Contrast Enhancer work as Quencher
and increase PR adhesion.

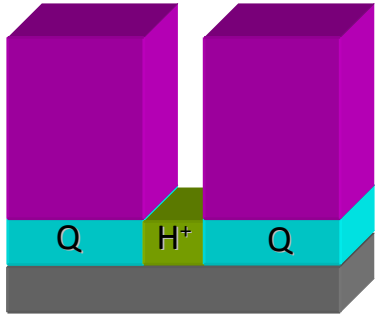
At EUV exposure area,
Contrast Enhancer generate acid
and promote the PR protonation.



*More Acidic surface area
(or High dose area)



*Less acidic surface area
(or Low dose area)



At high dose area,
PR cannot collapse due to Quencher component
from Contrast Enhancer.
At low dose area,
PR can resolve due to acids from Contrast Enhancer.

Contrast Enhancer ~EUV X-SEM~

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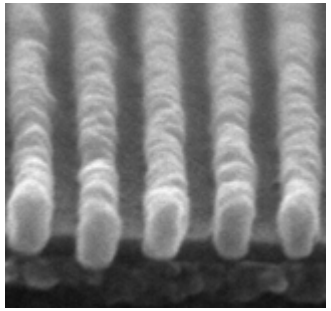
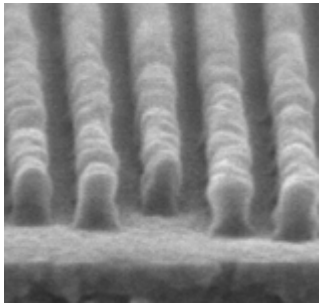
Data Courtesy of EIDEC

Tool : SFET (Small Field Exposure Tool)
Condition : Annular (0.3/0.7) NA=0.3
PR : ESR1

Target CD: 30nm hp

Si-HM		1st gen. std. Si-HM	Contrast Enhancer type Si-HM
X-section SEM image		 Undercut	 Slightly footing
CD	nm	29.9	29.2
Max EL	%	13.4	**20.4**
LWR	nm	5.5	**4.9**
Sensitivity	mJ/cm^2	**14.6**	15.9
Resolution	nm hp	30	**<26**

Contrast Enhancer also can improve EL margin, LWR & Resolution.

Contrast Enhancer ~Process window~

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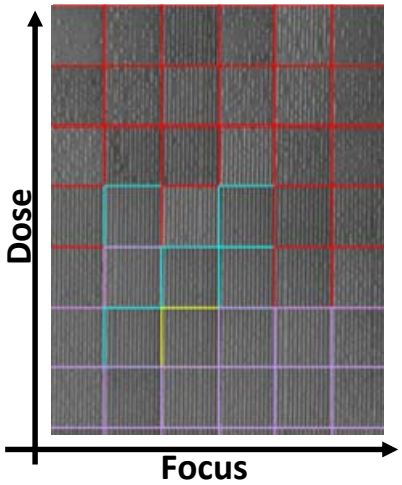
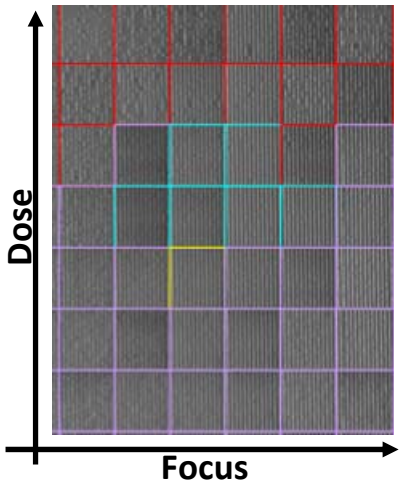
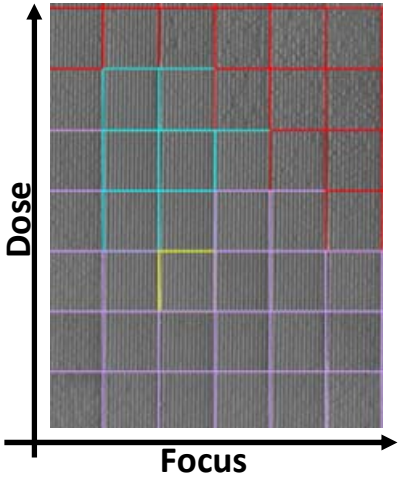
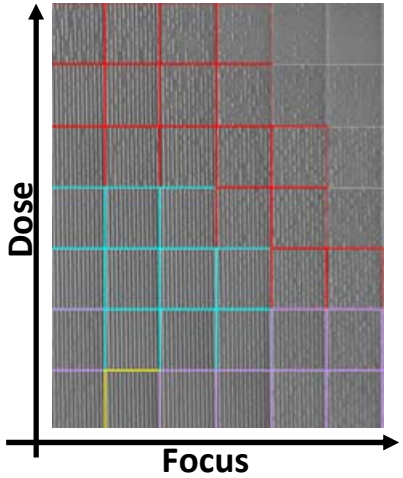
Hp 26nm

SEMATECH

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

Good **Eop** **Scum Bridge** **Collapse**

1st gen. Std. Si-HM	Contrast Enhancer (A)	Contrast Enhancer (B)	Contrast Enhancer (C)
			
Good shot : 6	Good shot : 7	Good shot : 8	Good shot : **11**
LWR : 6.0nm	LWR : 5.6nm	LWR : 5.5nm	LWR : **5.3nm**

Contrast Enhancer showed much better LWR & process window.

New Nissan EUV Si-HM : NCX7300

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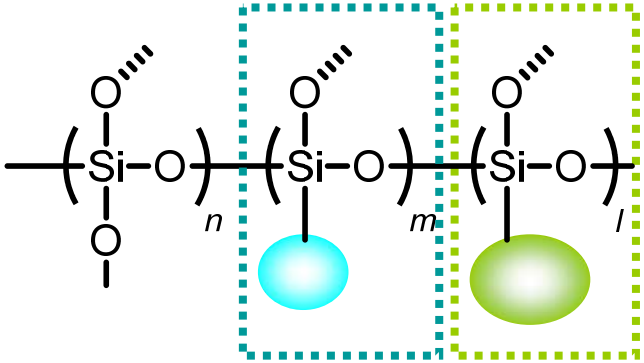
Key concept for the achievement of 2nd gen. Si-HM for around Hp 20nm.

Base polymer



EUV chromophore & Radical generation unit
*** High sensitivity**

High X-link unit
***Wide process margin**

+

Additives

Strong X-link catalyst
*** High resolution**

Contrast Enhancer
*** Wide process margin & low LWR**

New Nissan EUV Si-HM : NCX7300

SEMATECH

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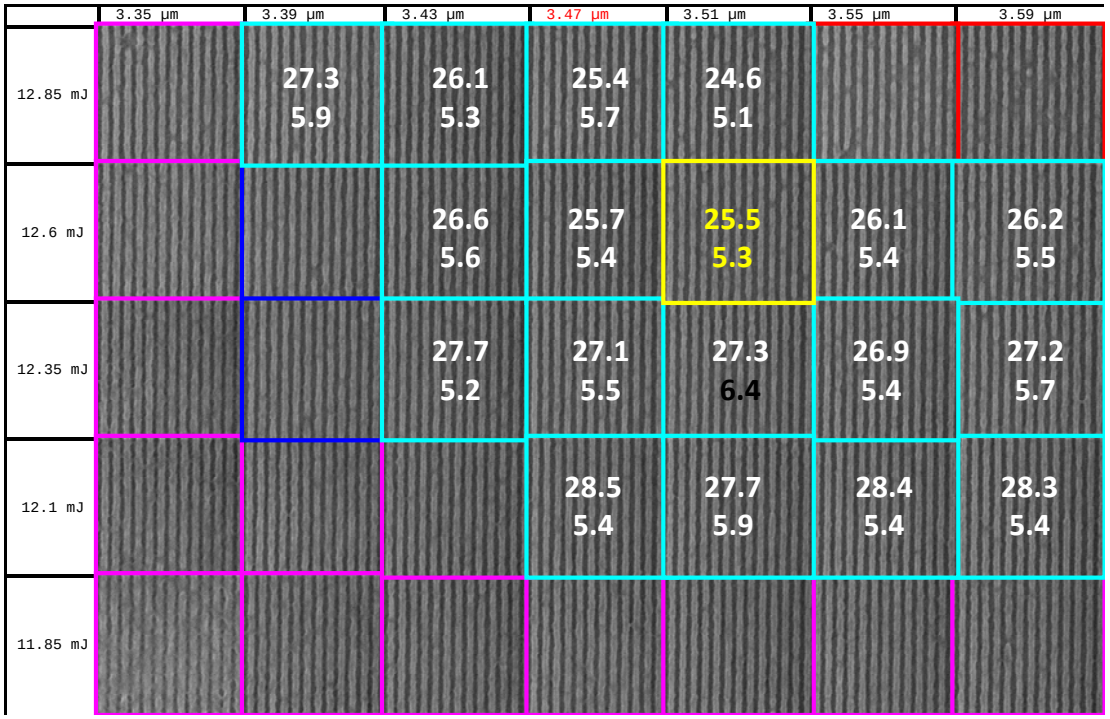
Hp 26nm

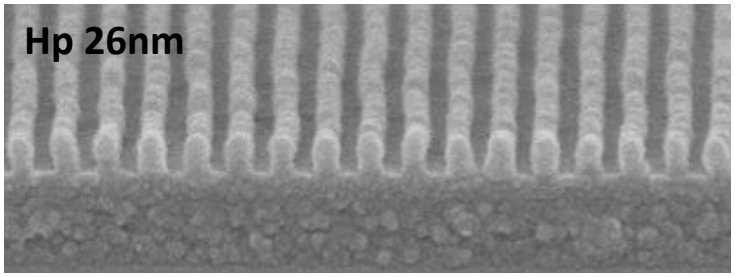


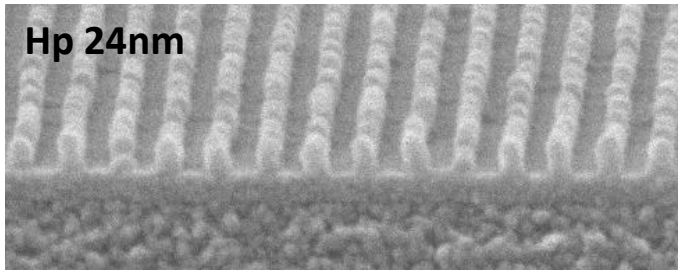
Tool : MET (Micro Exposure Tool)
Condition : Quadropole (0.68/0.36)
PR : Std. PR

No bridge
No collapse
LWR<6nm
<±10% target CD

Eop
Scum
Bridge
Collapse

Under evaluation @ NXE3100





NCX7300 ~Etching demonstration~

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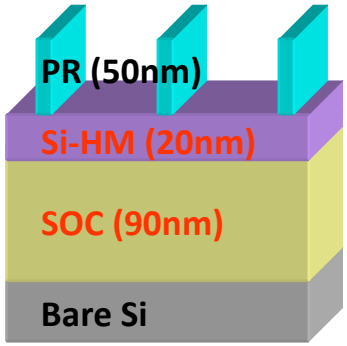
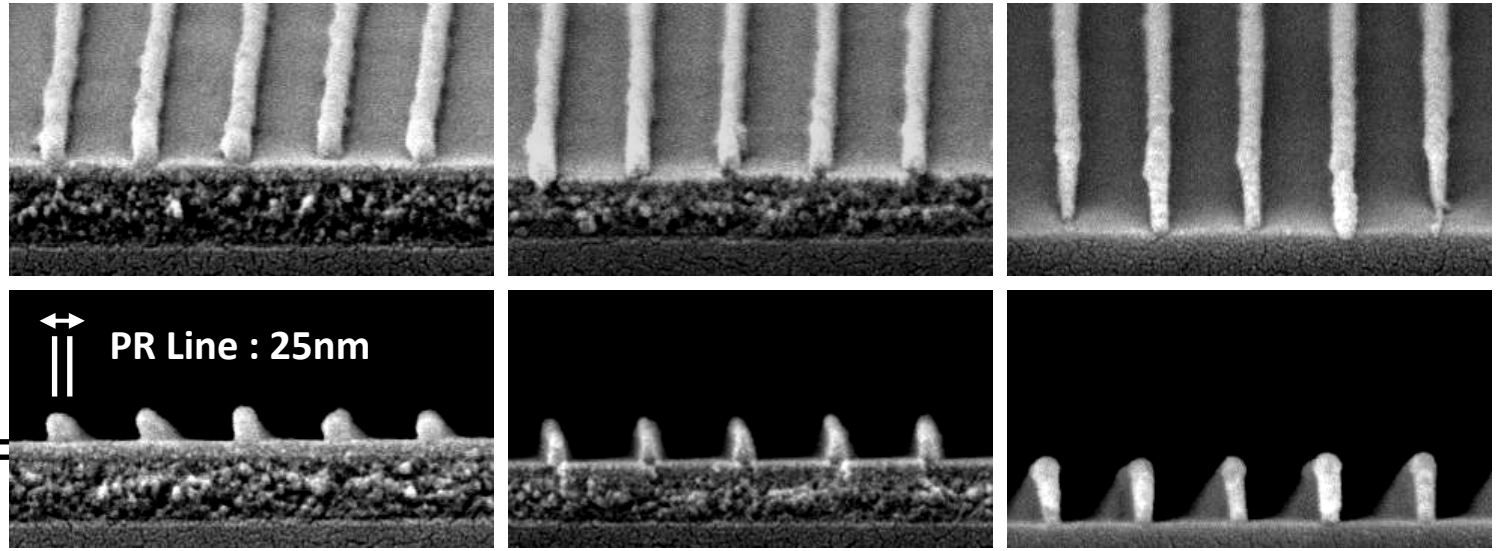


L/S : 25nm /130nm

Si-HM open : CxFy and others

SOC open : O_2 and others

Litho | **Si-HM Open** | **SOC Open**



Si-HM FTK : 20nm

Si-HM have enough etching resistance.

NCX7300A ~Outgass performance~

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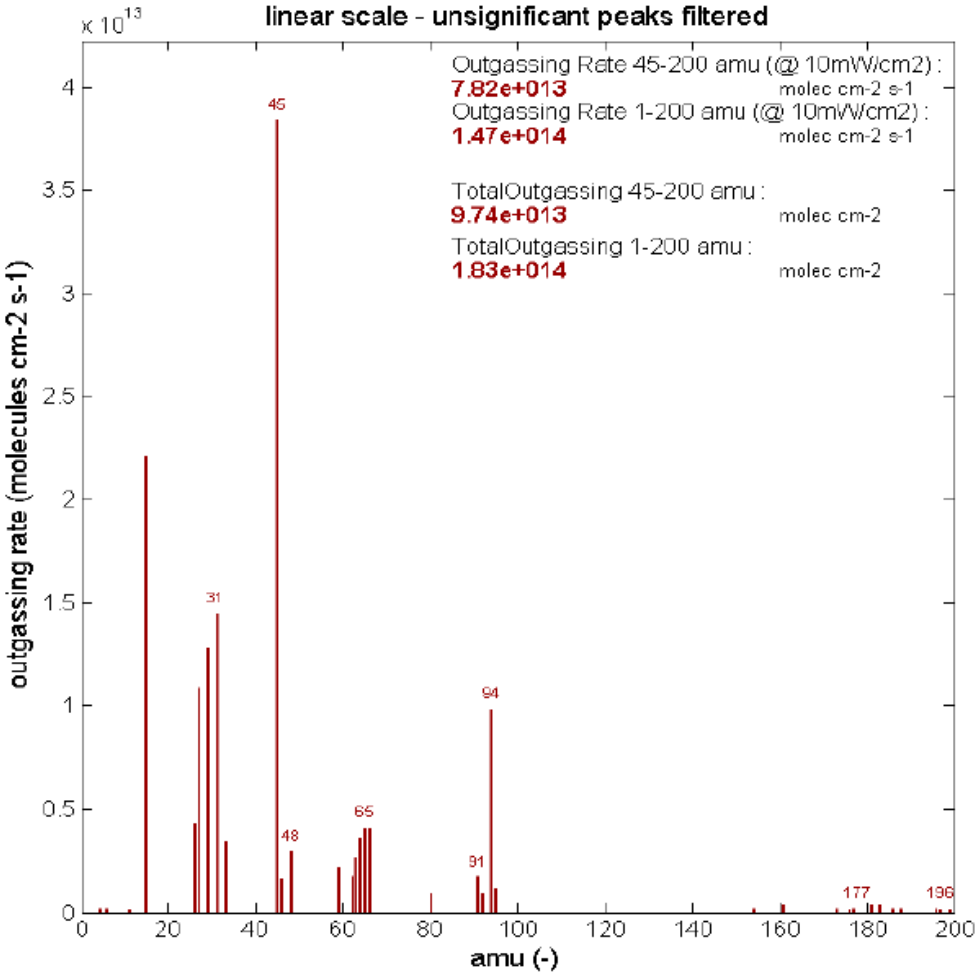
Challenging and Solution by x-layer



Background RGA		
WfrID		D14_LR080068
pressure at scan start (mbar)	5.00E-08	**5.00E-08**
power i0 at scan start (mW)	> 0.20	**0.264**
stage speed (mm/s)	1.06	**1.06**
scan pitch (mm)	2.50	**2.50**
no. of RGA cycles	< 31.00	**6**
Resist RGA		
WfrID		D05_LR06077
pressure at scan start (mbar)	5.00E-08	**5.00E-08**
power i0 at scan start (mW)	> 0.20	**0.264**
calculated stage speed (mm/s)	1.06	**1.06**
scan pitch (mm)	2.50	**2.50**
no. of RGA cycles	< 31.00	**6**
Result		
Pumping speed (l/s)		**258**
Power density (mW/cm2)		2.93
Outgassing rate 45-200amu (@10mW/cm2) (molecules cm-2 s-1) (calculated by Matlab routine)	< 5.00E+14	**7.82E+13** OK
max. individual peak in range 45-200	< 5.00E+13	**3.84E+13** OK

Outgassing property is also clear.

Summary

- EUV specific Si-HM have been developed.
- Radical generation unit & EUV Chromophore (Halogen, Hetero) can enhance sensitivity.
- X-link catalyst & high X-link polymer can increase resolution & LWR.
- Contrast Enhancer can improve LWR & process window.
- Nissan promotes NCX7300 for around Hp 20nm L/S of EUVL.