The Novel Spin-on Hard Mask and Ultra thin UL material for EUVL.

Nissan Chemical Industries, LTD.

R. Sakamoto, H.Yaguchi, S.Shigaki,
N.Fujitani, T.Endo, R.Onishi, B.C.Ho

Outline

NEXL™
Challenging and Solution by x-layer

1. Introduction of UL for EUVL.

2. Design and performance of EUV specific Si-HM.
   - Photo speed enhancement
   - Resist profile control
   - Introduction of 1st generation Si-HM for EUV (NCX7088A).

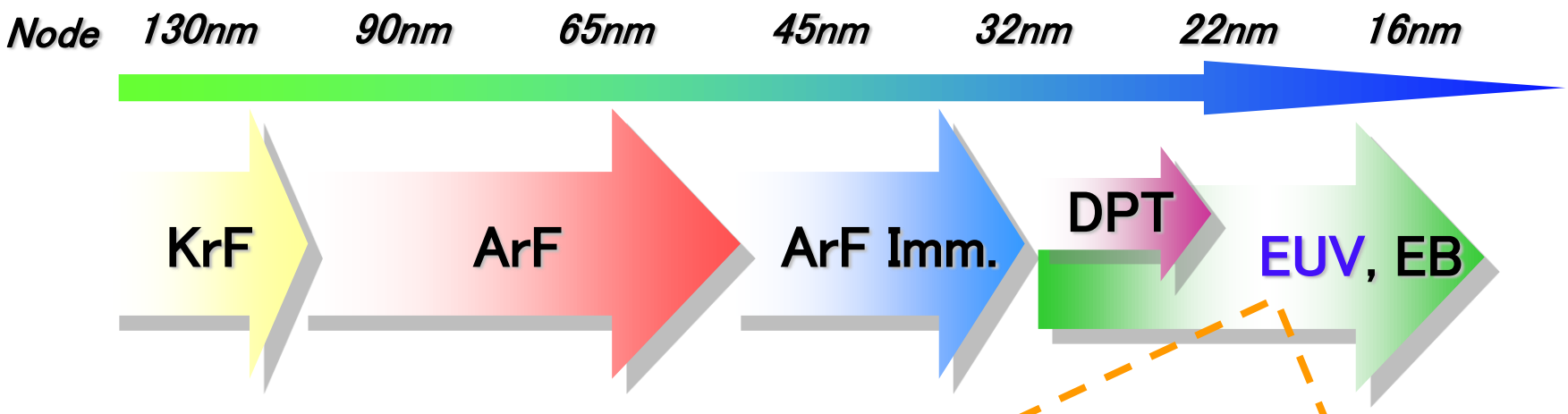
3. Introduction of Org.-UL for Ultra thin application (NCX1265).

4. Conclusion

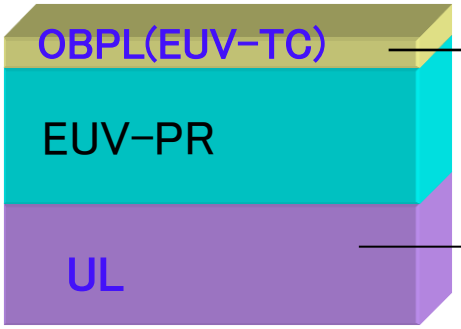
Introduction

NEXL™
Challenging and Solution by x-layer

▪Lithography Technology trend



▪NCI R&D Activity for EUVL

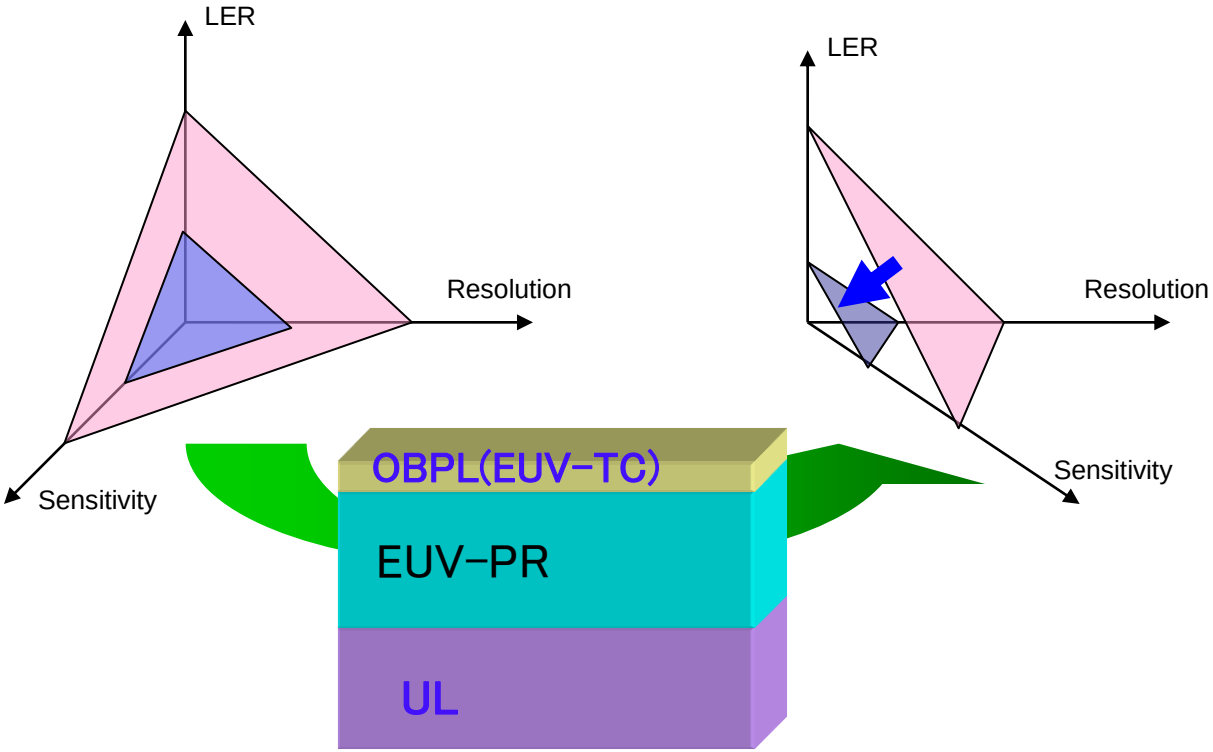


***OBPL*(OoB Protection Layer), *Poster* session.**

Org.-UL*, *Poster session

Si-HM* , *This Presentation

RLS trade off

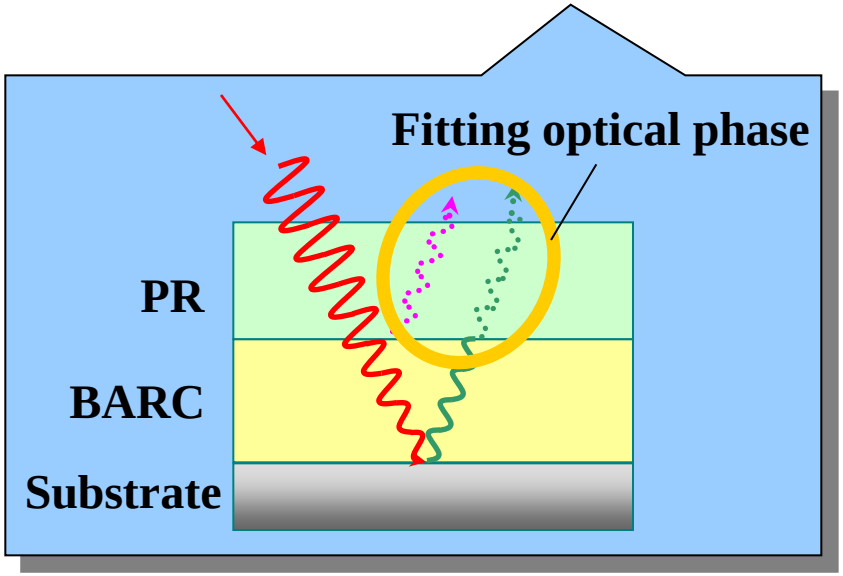


Motivation:
Help to minimize RLS trade off by Appling TC and UL.

Introduction

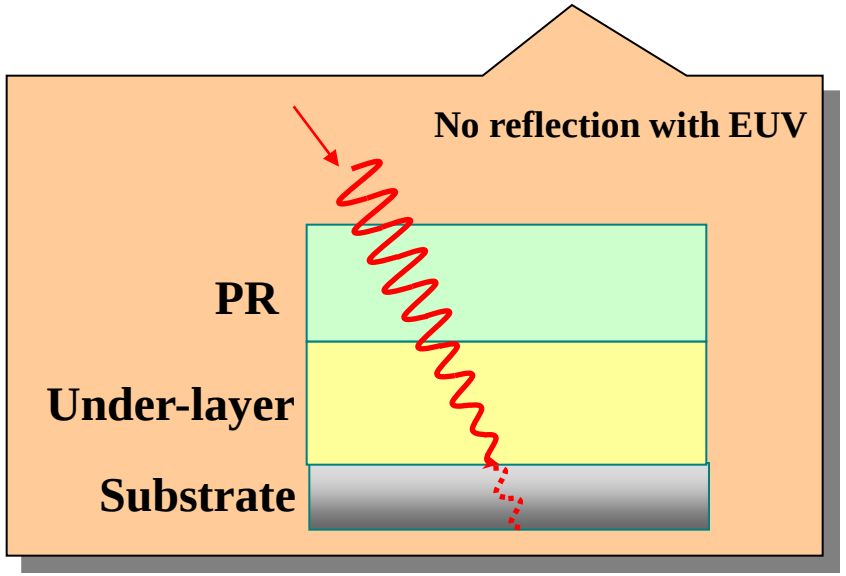
NEXL™
Challenging and Solution by x-layer

Optical Lithography
(with g-line, i-line, KrF, ArF)



Reflectivity control is the key factor.
BARC material is necessary for Optical Lithography.

EUV Lithography
(with 13.5nm)

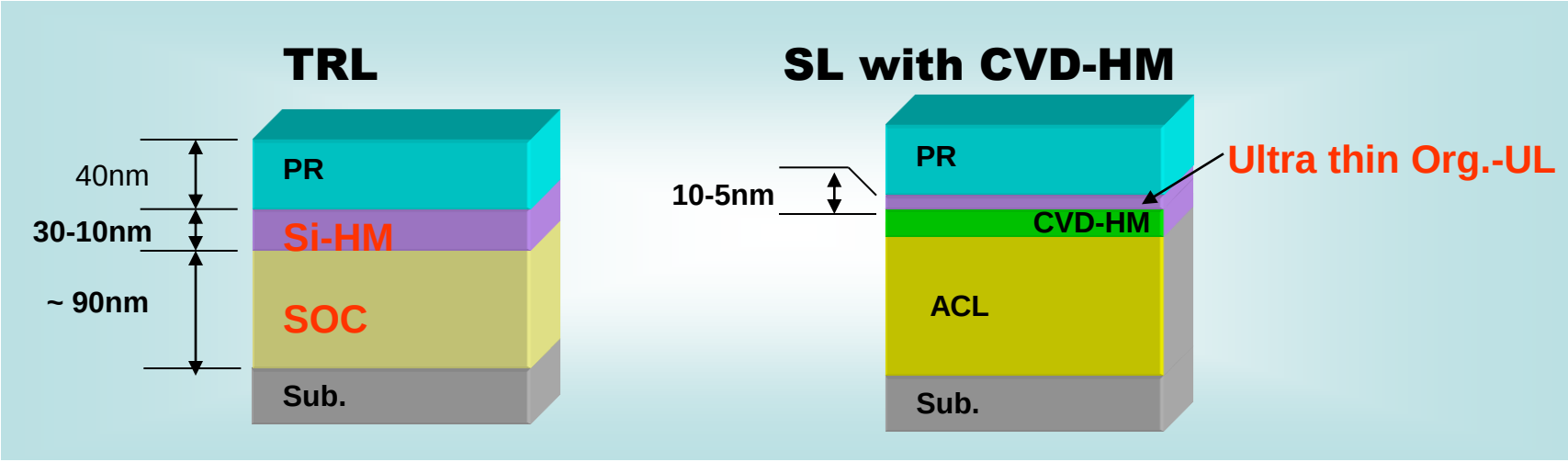


Main purpose is not reflectivity control.
Resist profile and adhesion control are Key function.

Introduction

NEXL™
Challenging and Solution by x-layer

Target material for UL



NCI's Basic technology:

- Organic and Inorganic polymer design and Synthesis
- Film surface Acidity control
- Acid or quencher Diffusion control
- Defect control, etc

Development of Si-HM and Ultra thin Org.-UL for EUV

Outline

1. Introduction of UL for EUVL.

2. Design and performance of EUV specific Si-HM.
   - Photo speed enhancement
   - Resist profile control
   - Introduction of 1st generation Si-HM for EUV (NCX7088A).

3. Introduction of Org.-UL for Ultra thin application (NCX1265).

4. Conclusion

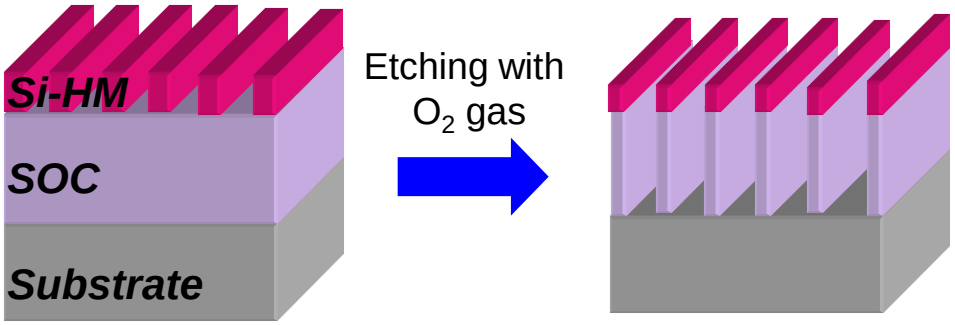
General requirement for Si-HM.

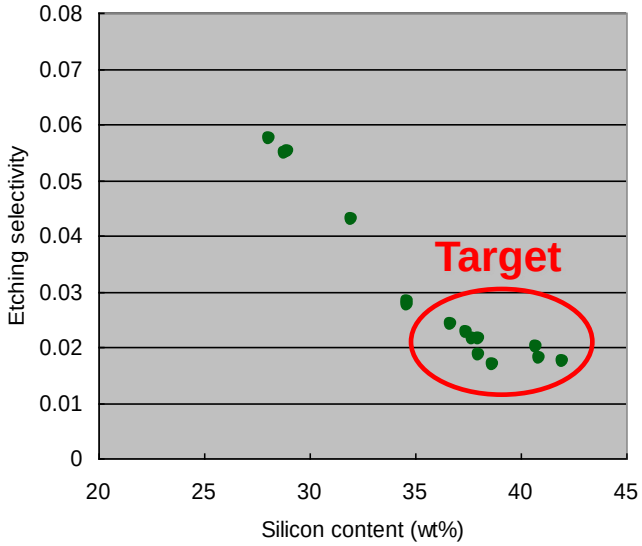
NEXL™
Challenging and Solution by x-layer

- *High Etching Resistance*

(Silicon content , O_2 Etching rate)

- More than 35 to 40wt% is necessary in this application.





- *Shelf life*

- Interaction control

  - Solvent – polymer interaction

    ; solubility {Dielectric constant (ε)} vs coating properties {surface tension (γ)}

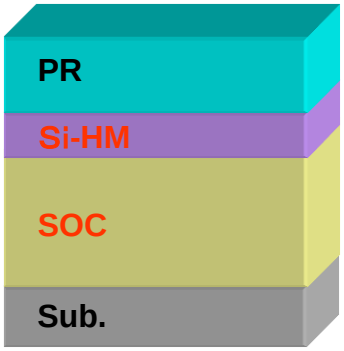
  - Stabilize reagent

    ; stabilize X-linked group

- *Resist Compatibility*

Requirement of Si-HM for EUVL

1. **Low outgassing without non-cleanable species.**
2. **Good Lithography performance with EUV exposure.**
3. **Good coating performance with thin FTK (FTK<30nm).**
4. Enough etch resistance (High Si content >40%).
5. Good aging stability.

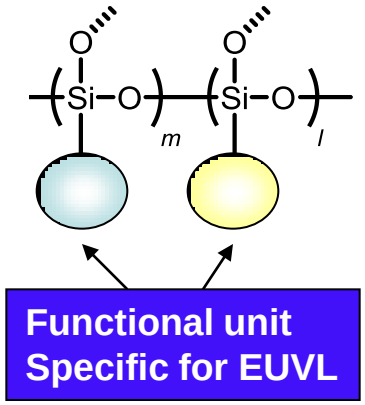


What's the specific design for EUVL

NEXL™
Challenging and Solution by x-layer

Material Design for EUVL

Si-HM material

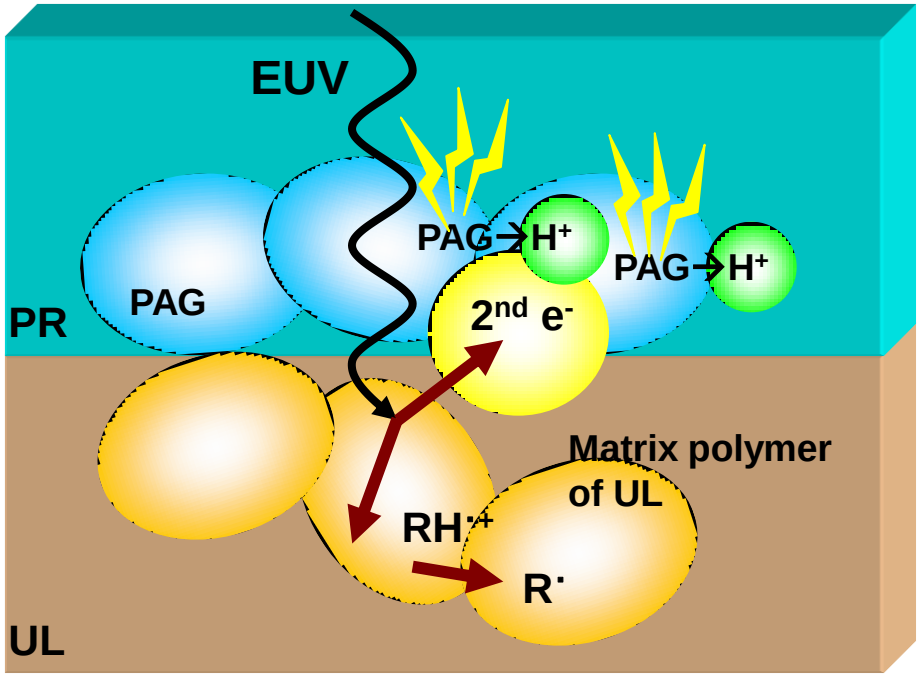


- **Photo-speed enhancement**
  - Loading EUV choromophre or radical generation unit
- **LWR Improvement**
  - Profile control unit (less footing/scumming)
- **Resolution:**
  - Pattern Collapse Reduction at over dose area
  - Line bridging reduction at under dose area
  - Profile control unit (less footing/scumming)
  - Loading adhesion unit

Photo-speed enhancement

NEXL™
Challenging and Solution by x-layer

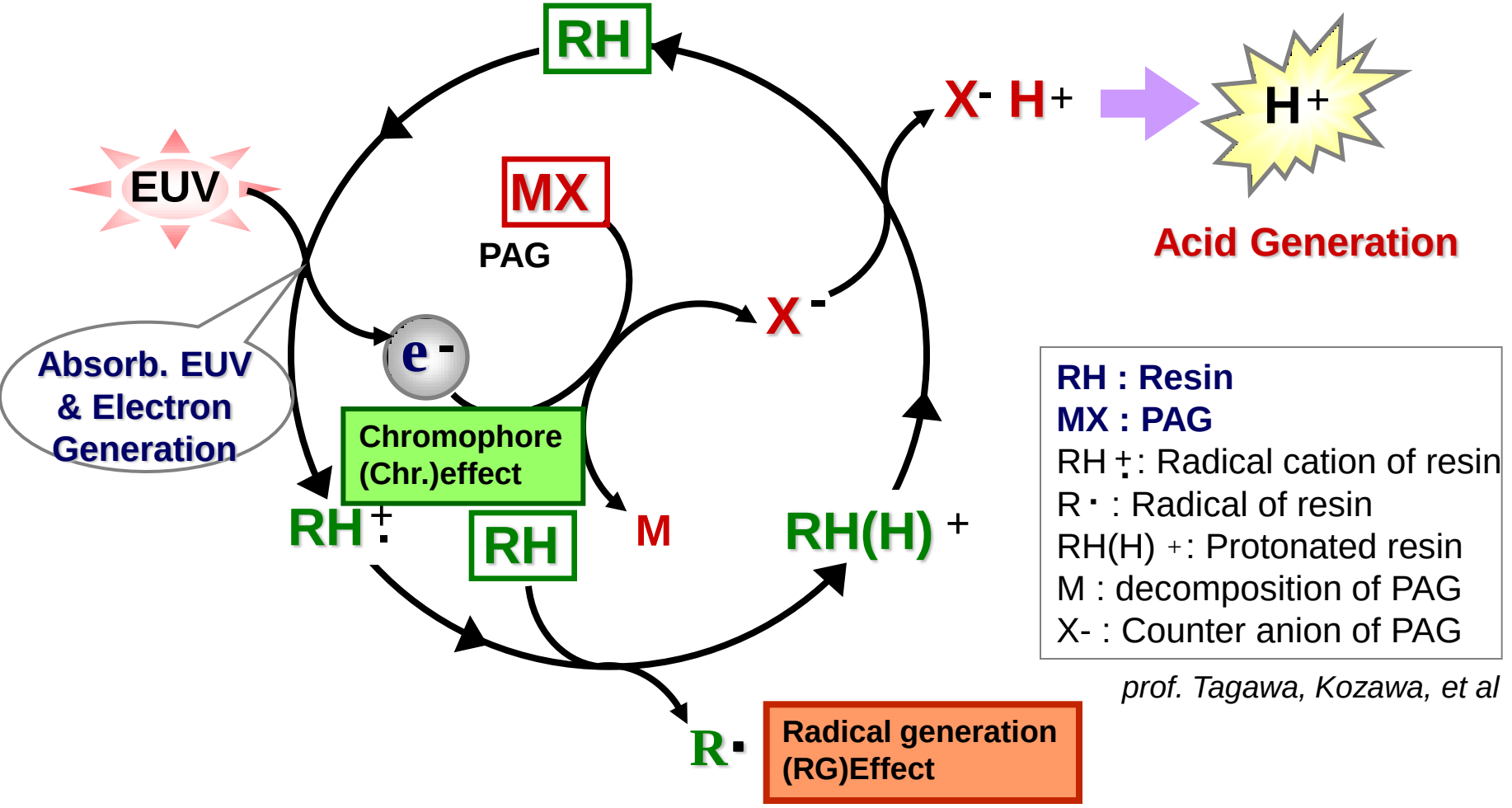
Acid generation mechanism



Understanding acid generation behavior at PR and UL interface is important to understand the EUV lithography performance.

Acid Generation Mechanism from PAG

NEXL™
Challenging and Solution by x-layer



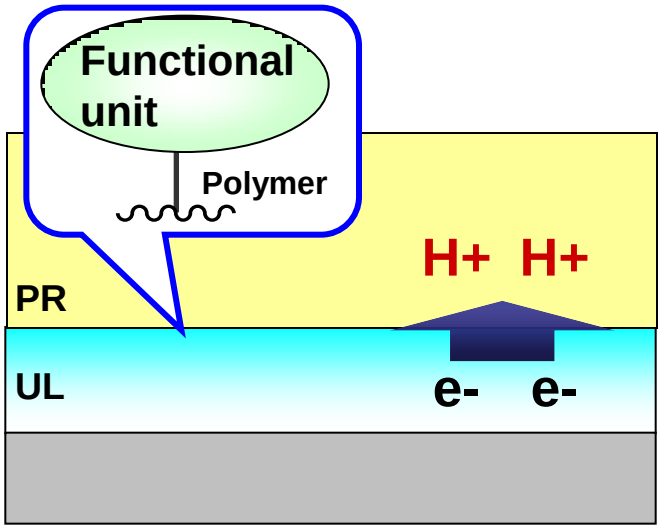
RH : Resin
MX : PAG
RH +·: Radical cation of resin
R · : Radical of resin
RH(H) +: Protonated resin
M : decomposition of PAG
X- : Counter anion of PAG

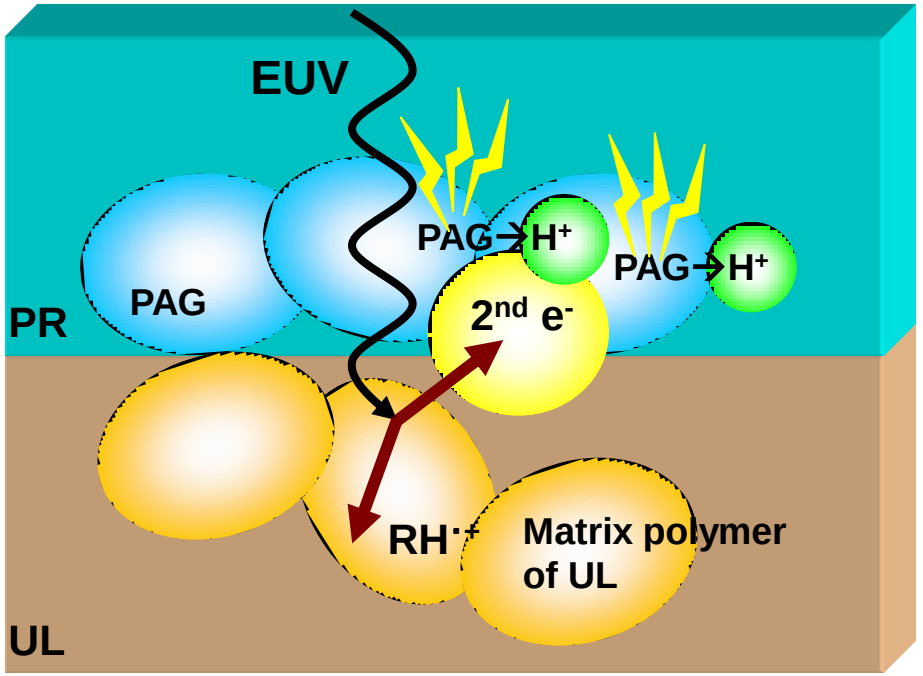
prof. Tagawa, Kozawa, et al

Point for acid generation;
1. **How much absorb EUV light (Chromophore unit)**
2. **How easily generate radical (Radical generation unit)**

Photo-speed enhancement

NEXL™
Challenging and Solution by x-layer

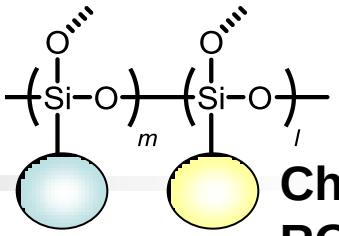




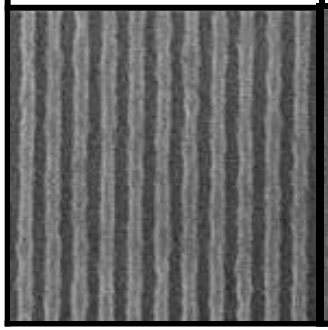
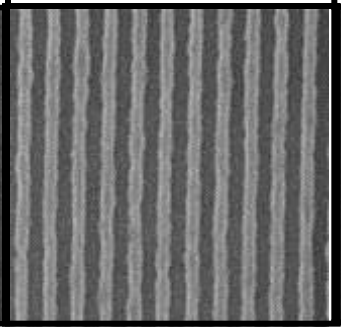
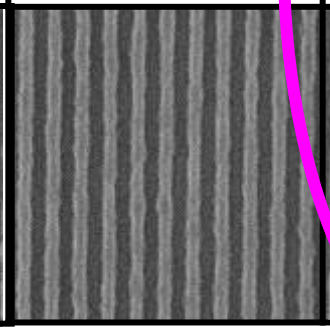
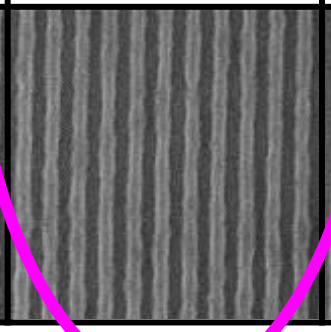
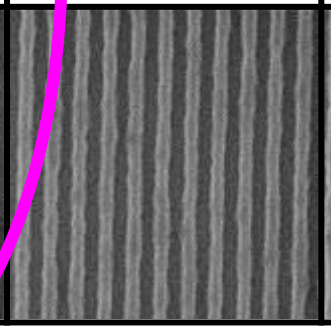
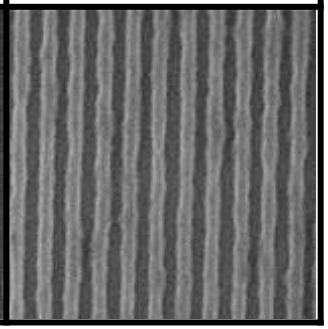
Introduction of
- **EUV Chromophore unit**
- **Radical generation unit (RG unit)**

into Si-HM base polymer.

Photo-speed enhancement



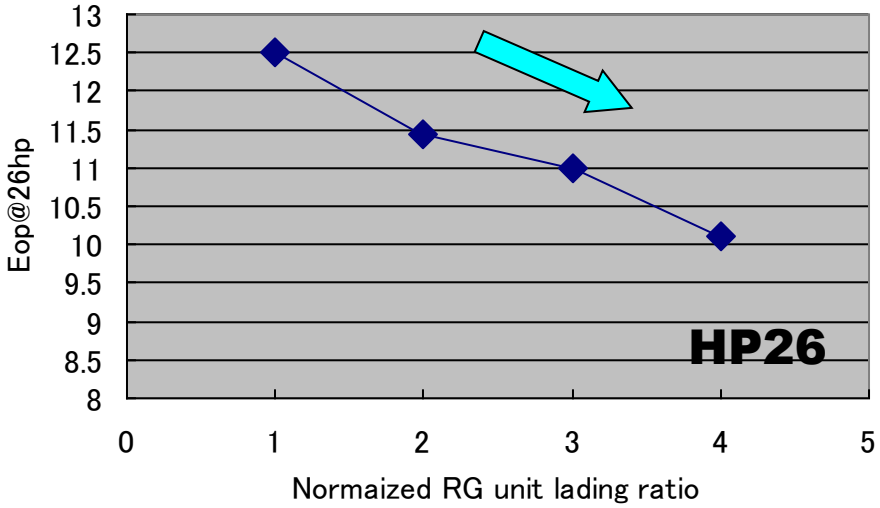
Chr. unit
RG unit

	Including Chromophore	Including Radical Generation unit			
STD	UL-A	UL-B	UL-C	UL-D	UL-E
Eop: 13.0mJ	10.08mJ	10.58mJ	11mJ	11mJ	11mJ
LWR: 6.7nm	6.2nm	6.4nm	6.1nm	8.7 nm	6.9 nm
CD: 28.7nm	29.2nm	29.3nm	28.8 nm	28.6 nm	29.4 nm
	Ch-A	RG-A	RG-B	RG-C	RG-D
					

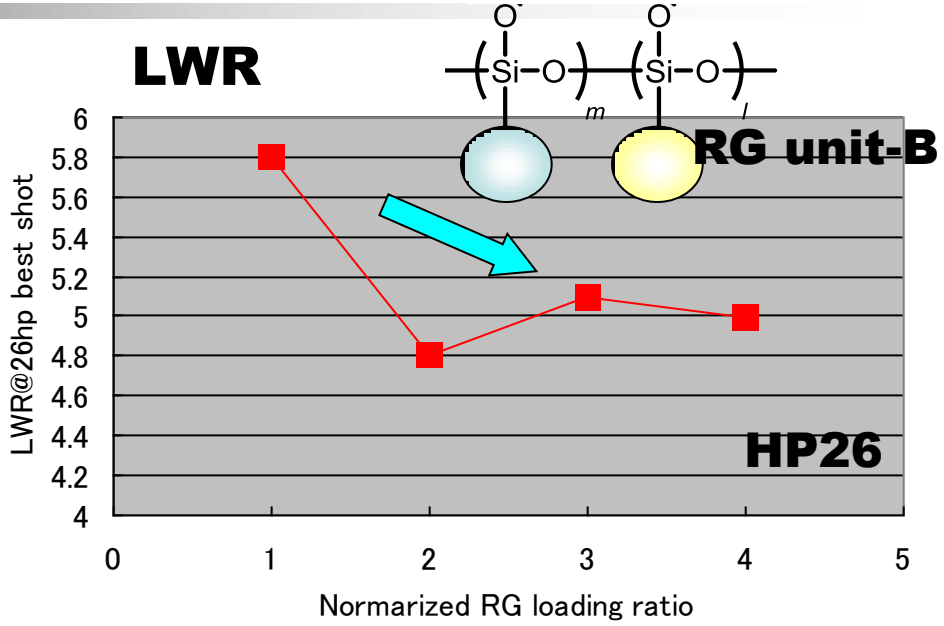
Including Chromophore unit and All of 4 type RG unit could enhanced the photo-speed.

RG-B loading level and Lithography performance

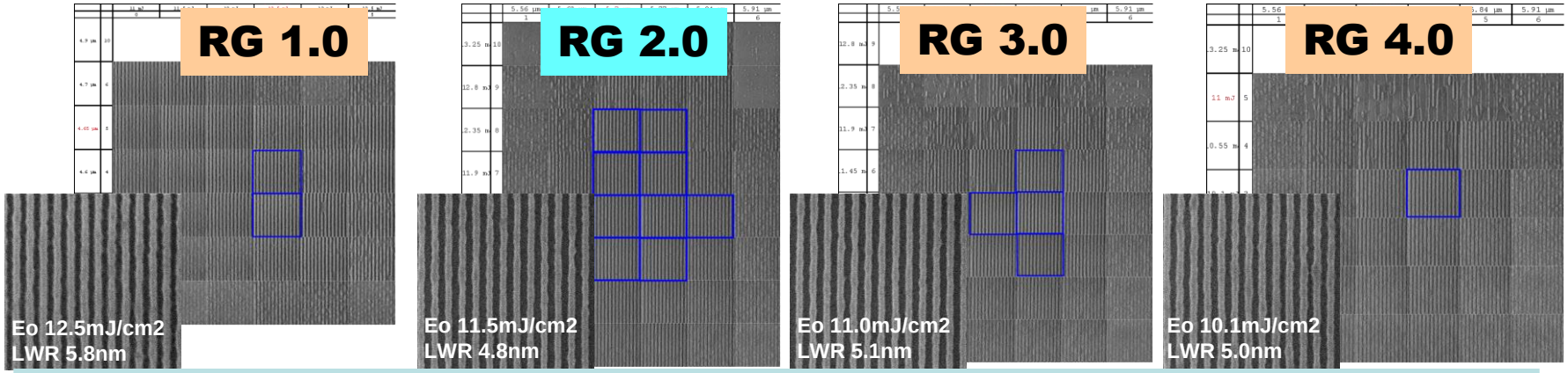
Photo-Speed



LWR

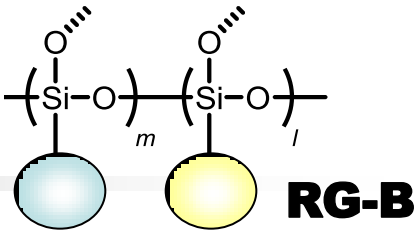


PW

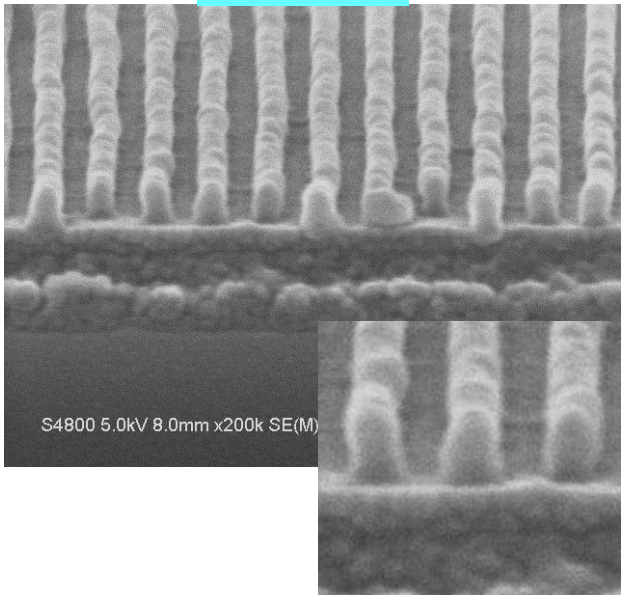


High RG-B loading increased photo-speed, but too much loading could make PW worse.

RG-B loading level and Profile

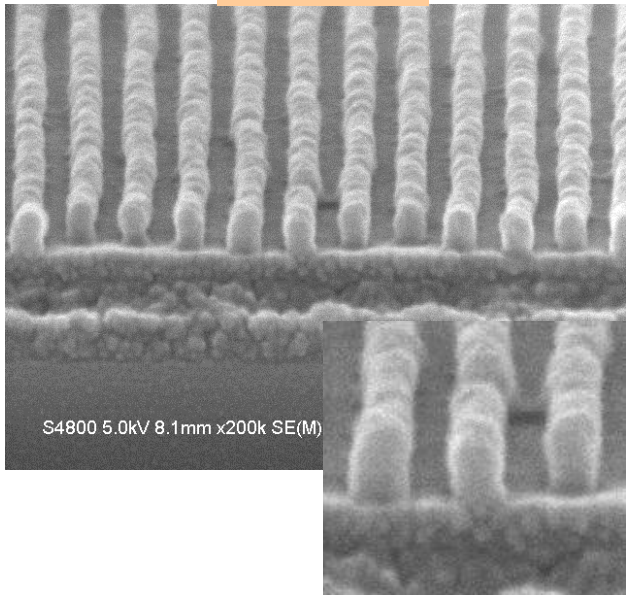


RG 2.0



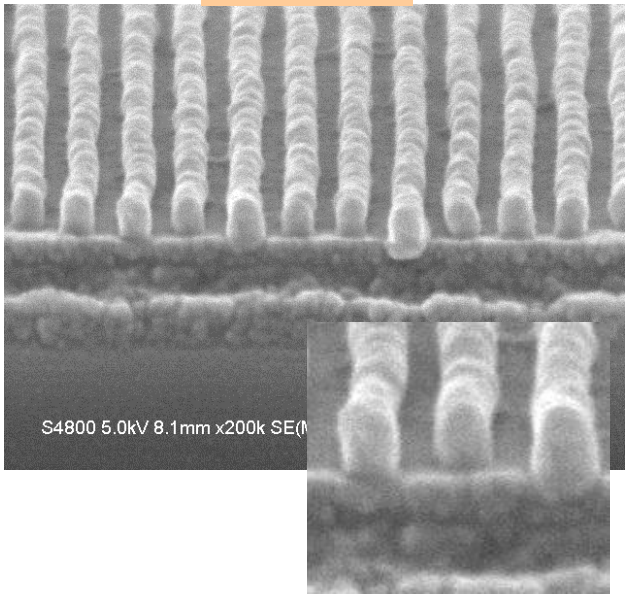
Slightly footing~Straight

RG 3.0



Slightly under cut

RG 4.0



Slightly under cut

High RG-B loading make resist profile under cut.
RG3.0 and 4.0 seems too much electron donation from Si-HM.
RG2.0 loading ratio showed the best PW, LWR and resist profile.

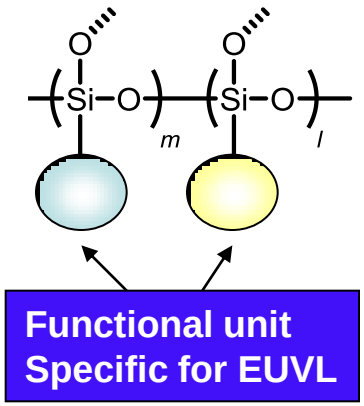
It is necessary to consider the suitable RG loading ratio to obtain Good lithography valance.

What's the specific design for EUVL

NEXL™
Challenging and Solution by x-layer

Material Design for EUVL

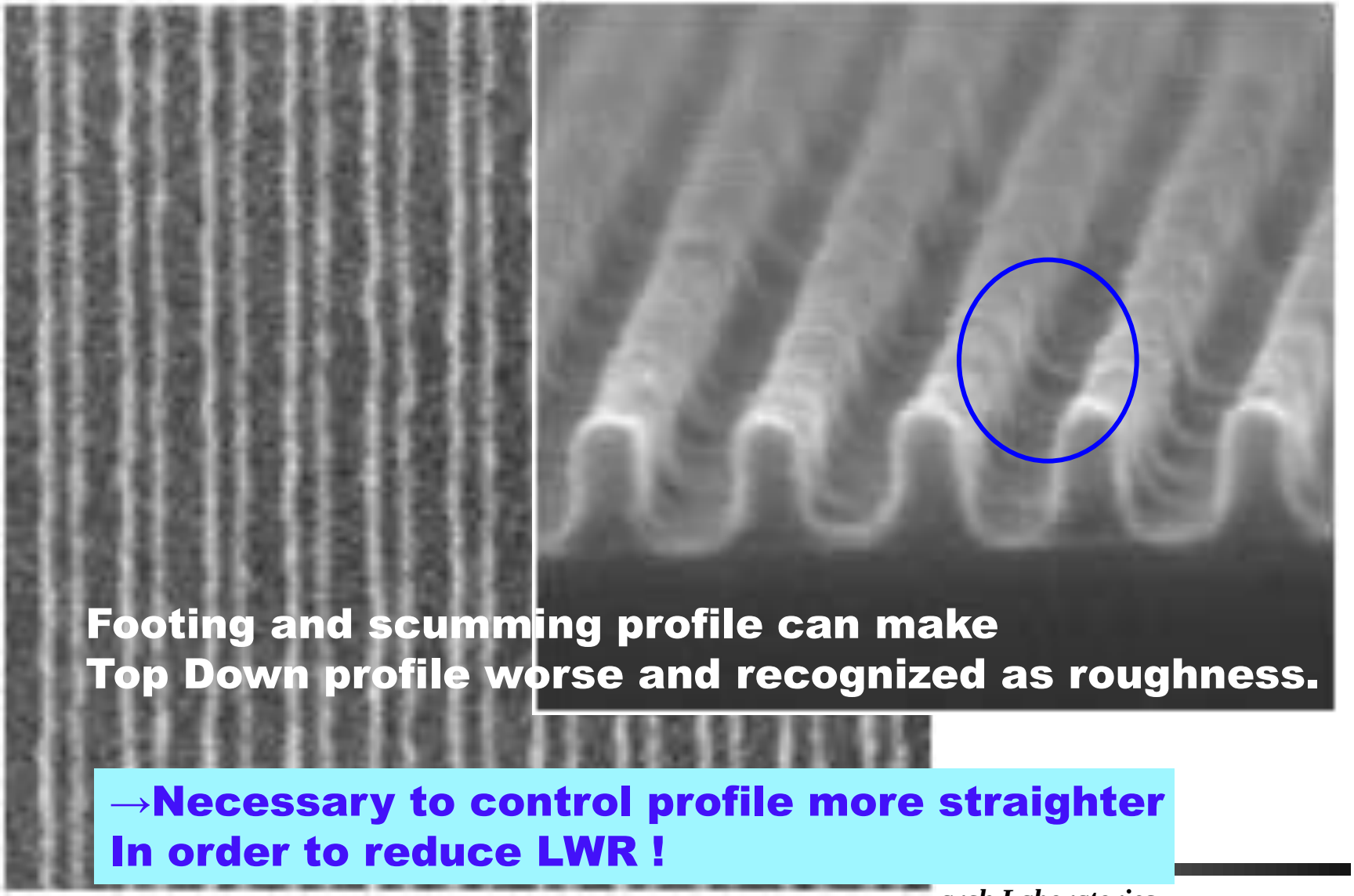
Si-HM material



- **Photo-speed enhancement**
  - Loading EUV choromophre or radical generation unit
- **LWR Improvement**
  - **Profile control unit (less footing/scumming)**
- **Resolution:**
  - **Pattern Collapse Reduction at over dose area**
  - **Line bridging reduction at under dose area**
  - **Profile control unit (less footing/scumming)**
  - **Loading adhesion unit**

Resist profile and LWR

NEXL™
Challenging and Solution by x-layer



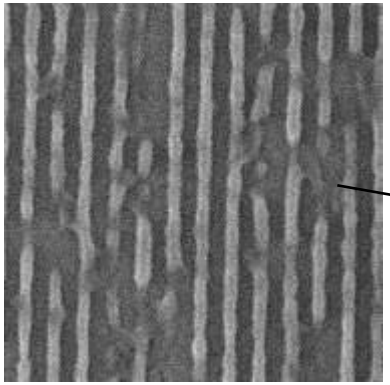
→Necessary to control profile more straighter In order to reduce LWR !

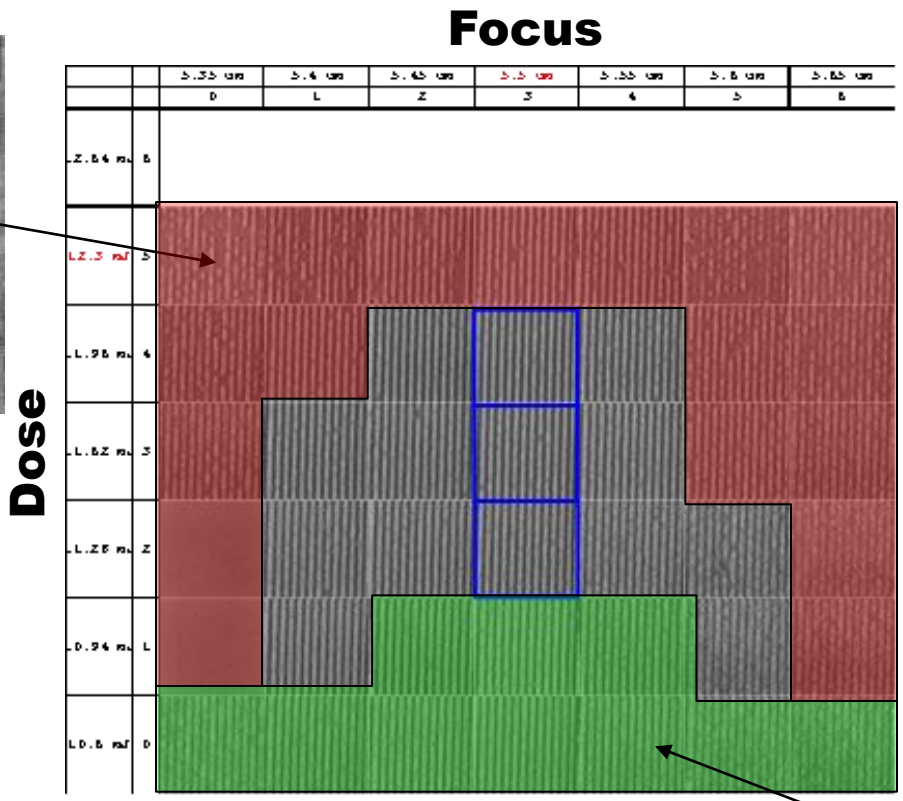
NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.
2011 EUV symposium in Miami

PW Limitation

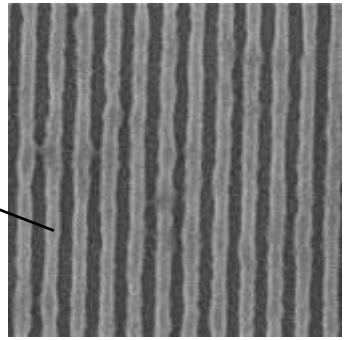
NEXL™
Challenging and Solution by x-layer

Line collapse





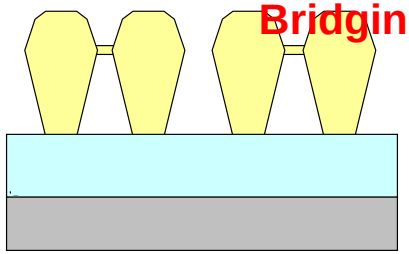
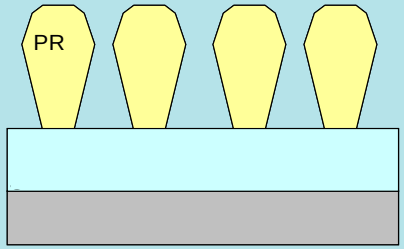
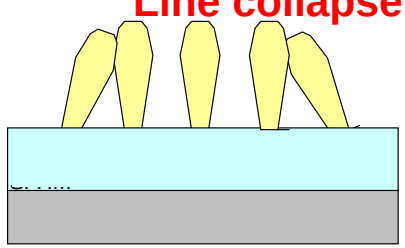
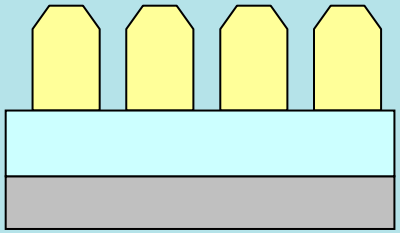
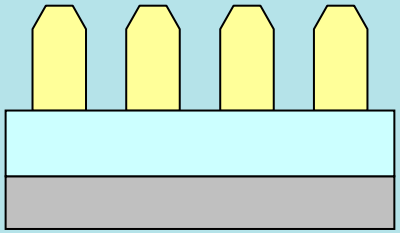
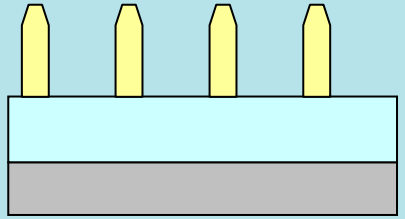
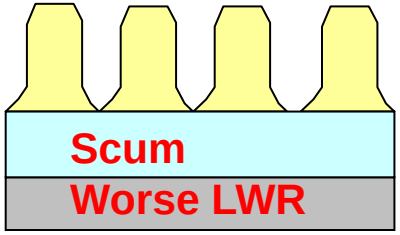
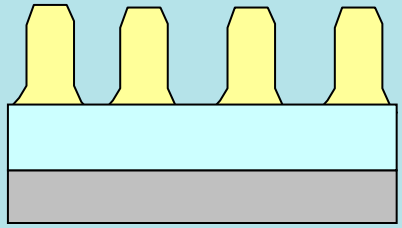
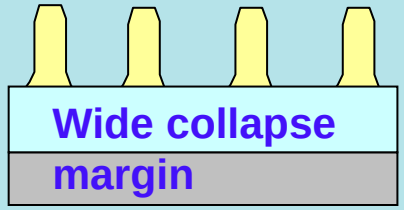
Line bridge



Line collapse and bridging are the key issue For the process window limitation.

Resist profile and Process Window

NEXL™
Challenging and Solution by x-layer

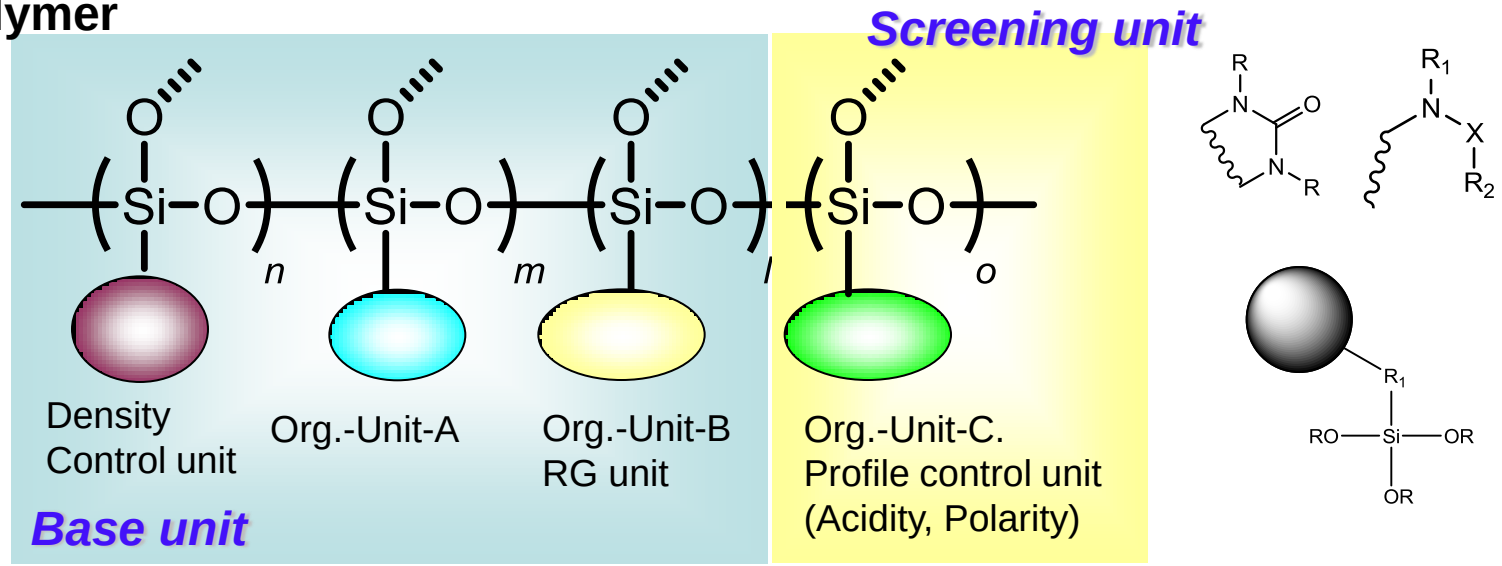
Profile	Under dose	Best Dose	Over dose
Under Taper			
Straight			
Footing			

Target profile **Vertical ~ Slightly rounding at top profile**
Straight ~ Slightly footing profile at bottom profile

Resist Profile control

NEXL™
Challenging and Solution by x-layer

Base polymer

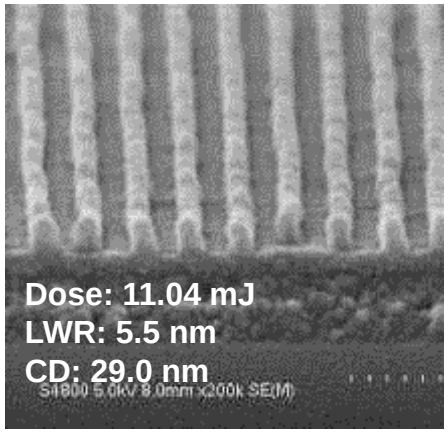
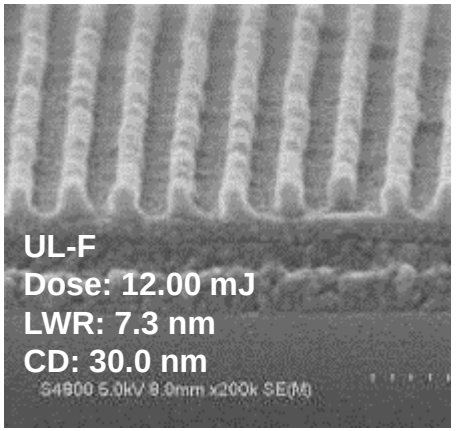
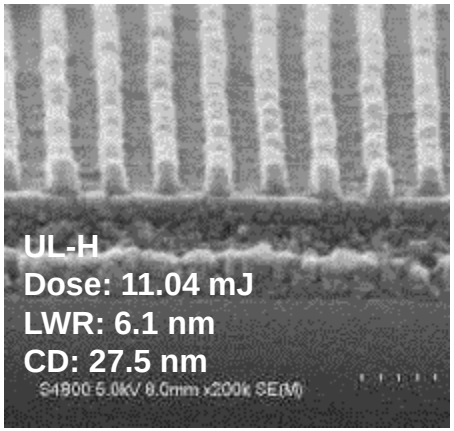
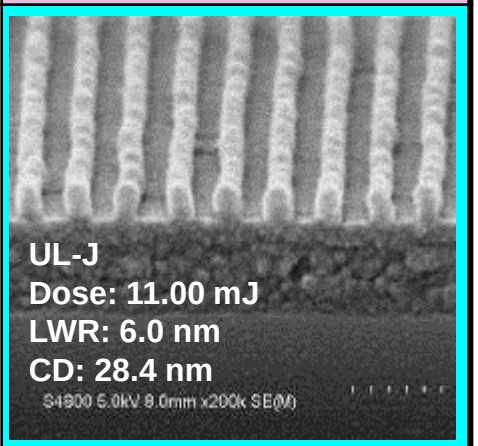
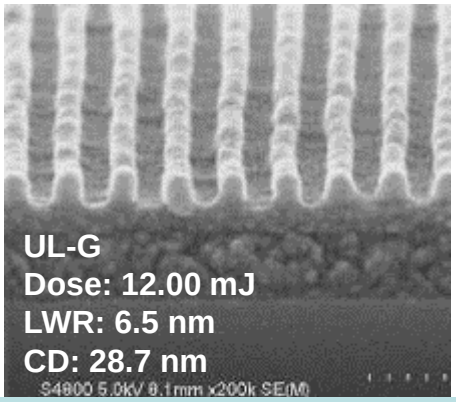
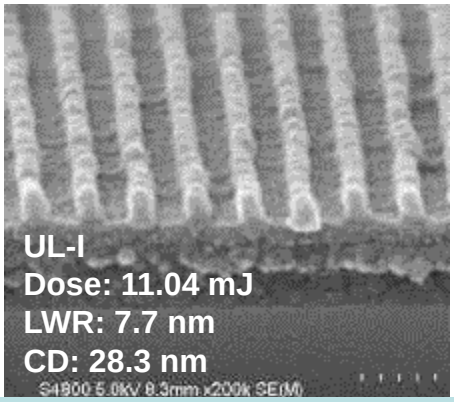
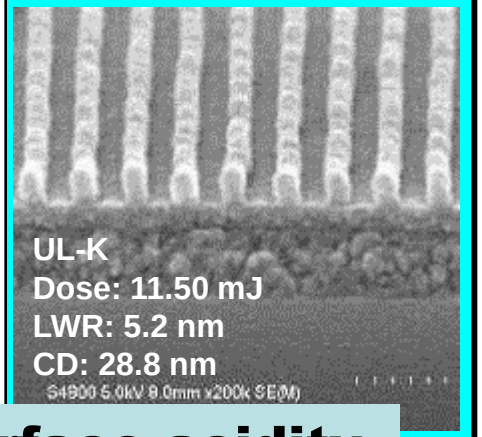


Sample	Profile control unit type	Lording ratio
Ref.	-	-
UL-F	Strong base	Low
UL-G		High
UL-H	Soft base	Low
UL-I		High
UL-J	Neutral acidity & Polarity	Low
UL-K		High

Resist Profile control

Upper low loading
Under high loading

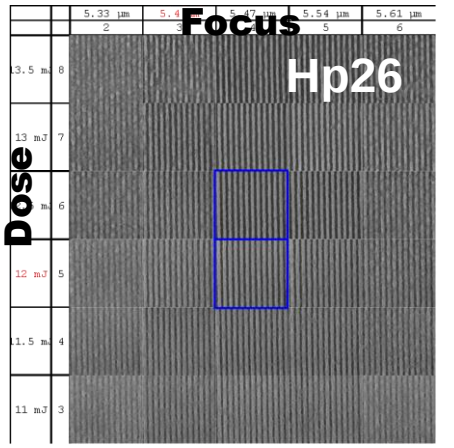
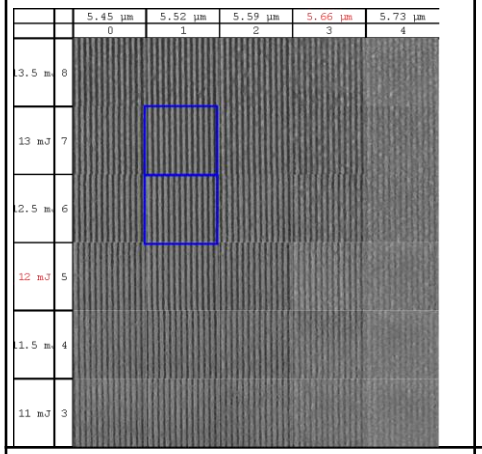
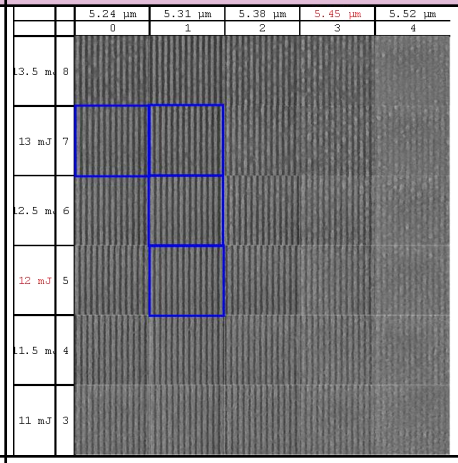
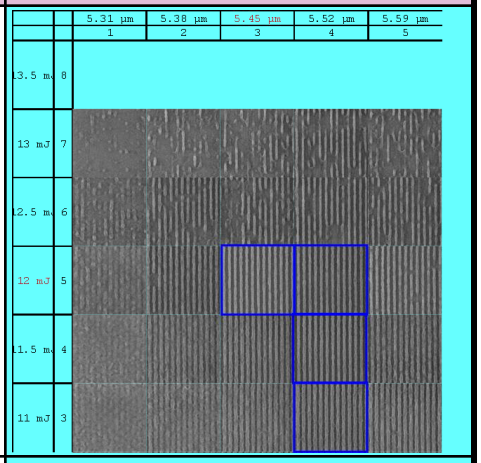
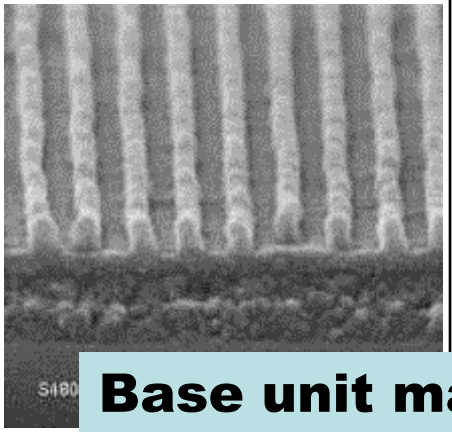
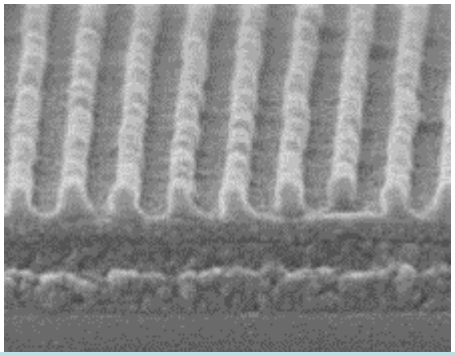
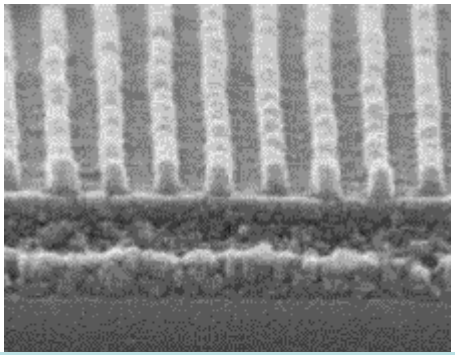
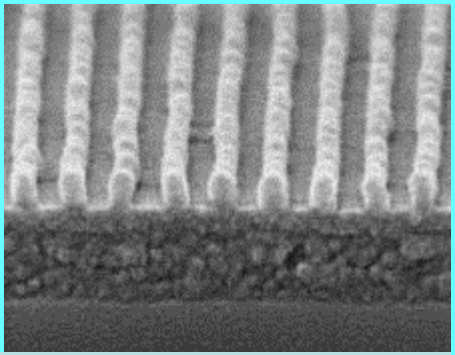
MET: 0.30NA, 0.68/0.36σ

Ref. (No profile control unit)	Strong base	Soft base	Neutral acidity & Polarity
 Slightly foot Wiggling			
			

The resist profile could be improved by surface acidity and polarity control.

Resist Profile control & PW

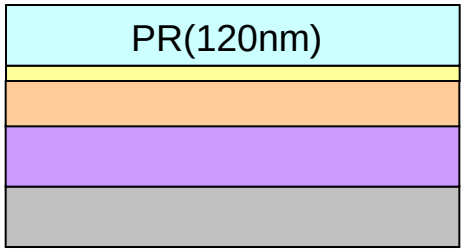
MET: 0.30NA, 0.68/0.36σ

Ref. (No profile control unit)	Strong base	Soft base	Neutral acidity & Polarity
			
			

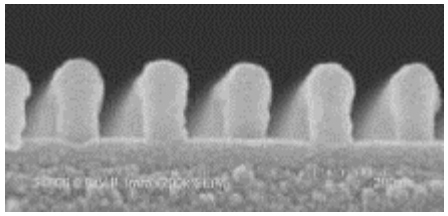
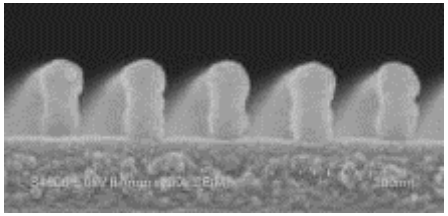
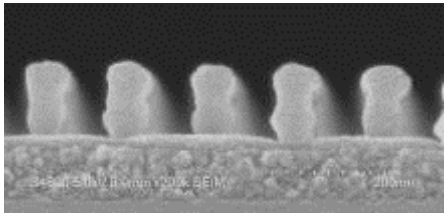
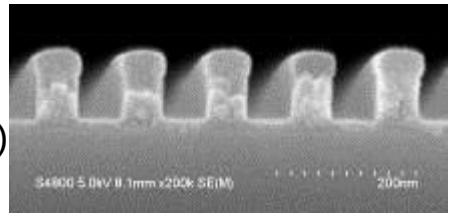
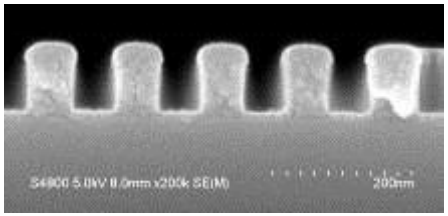
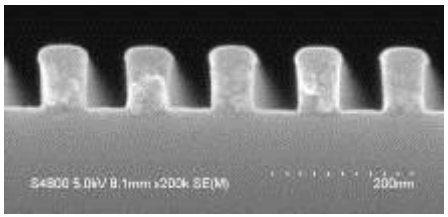
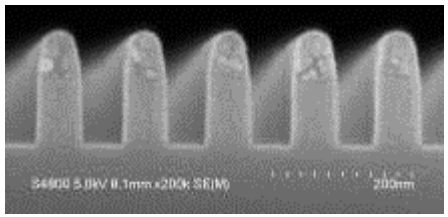
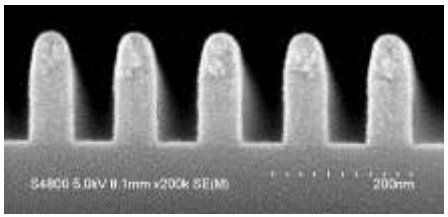
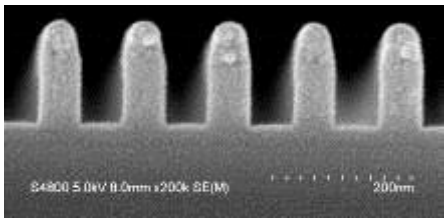
Base unit made collapse margin wider and Neutral acidity Unit made under dose margin wider. Choosing good acidity Valance is important to achieve wide PW.

Etching demonstration (HM FTK dependency)

CD 65nm



Si-HM(10, 20, 30nm Si 40wt%)
SOC (90nm)
Poly-Si (100nm)

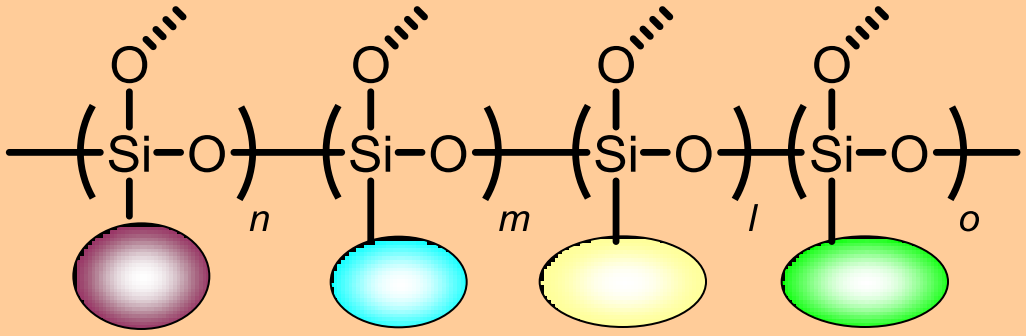
	Si-HM 30nm	**Si-HM 20nm**	**Si-HM 10nm**
Lihto (ArF)			
Si-HM&SOC open (CF /etc.→O2/etc.)			
Poly-Si open (HBr/etc.)			

Even 10nm Si-HM(40% Si) could successfully open SOC and HM.

Summary of Material design

NEXL™
Challenging and Solution by x-layer

Polymer design

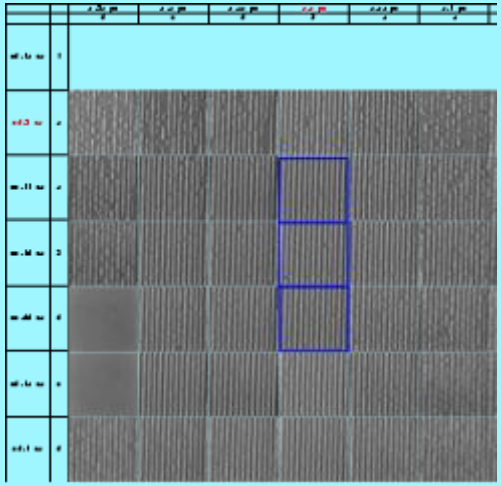


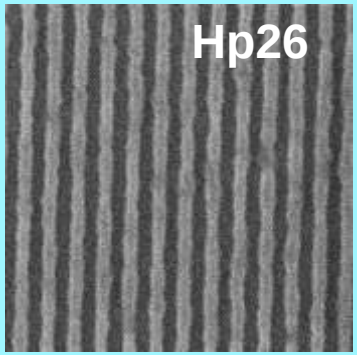
- **Radical generation unit can enhance Photo-speed and reduce LWR.**
- **Profile control unit can improve resist profile and make PW wider and could reduce LWR. Co-polymer ratio should be optimize to achieve the good lithography valance.**
- **Si content can be kept >40% for high etch resistance.**

1st Gen. Si-HM for EUV ~NCX7088A~

NEXL™
Challenging and Solution by x-layer

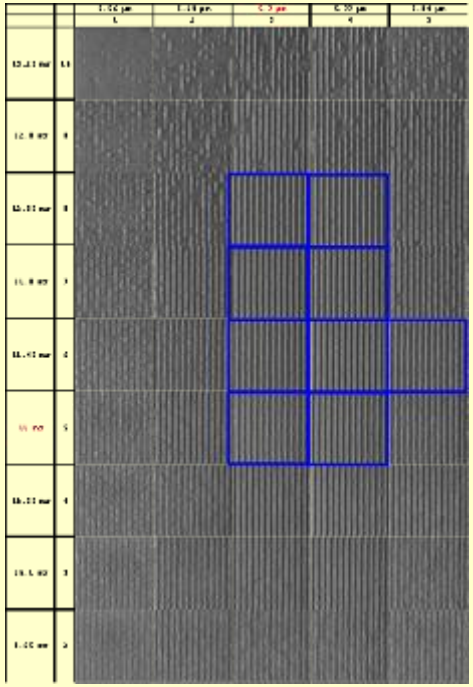
Control sample

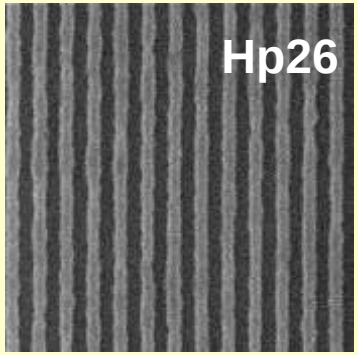




CD 25.3nm
Eop 11.28mJ/cm2
LWR 5.8nm
DOF 105nm

NCX7088A





CD 24.3nm
Eop 11.45mJ/cm2
LWR 4.8nm
DOF 140nm

SEMATECH

MET: 0.30NA, 0.68/0.36σ

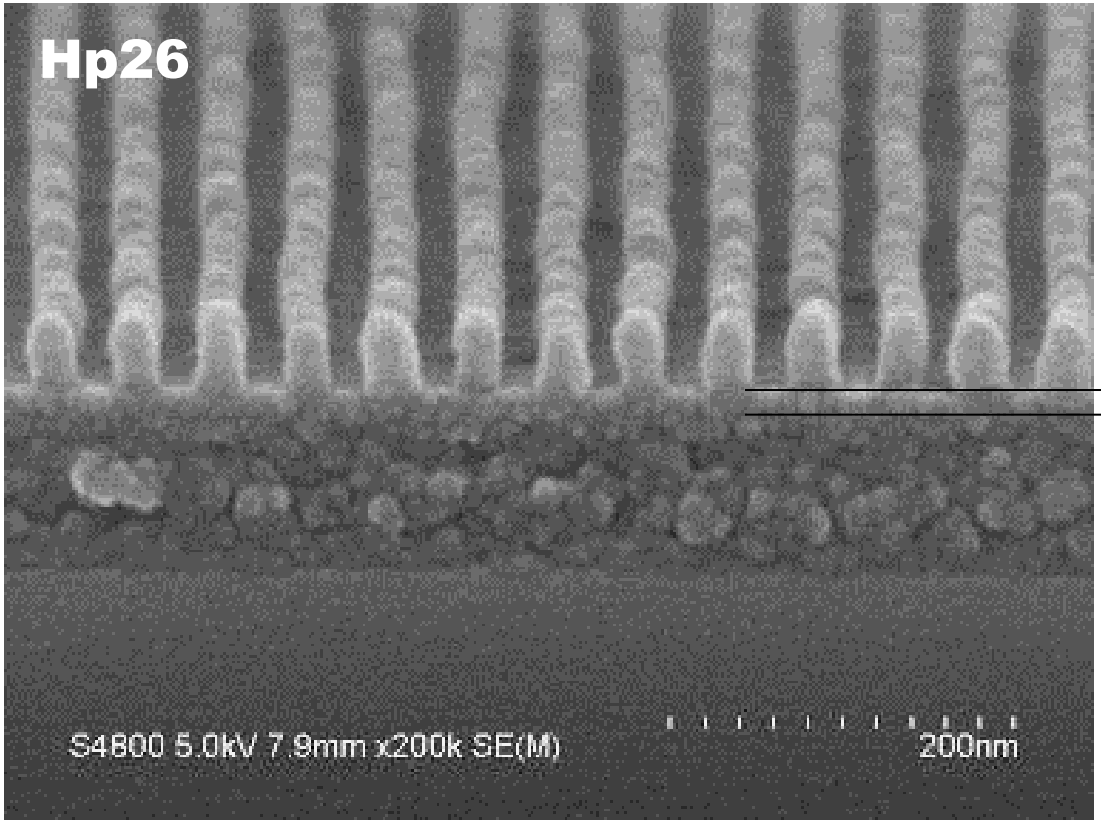
Reasonable Photo-speed and wide PW

EUVL Evaluation of NCX7088A

NEXL™
Challenging and Solution by x-layer

SEMATECH

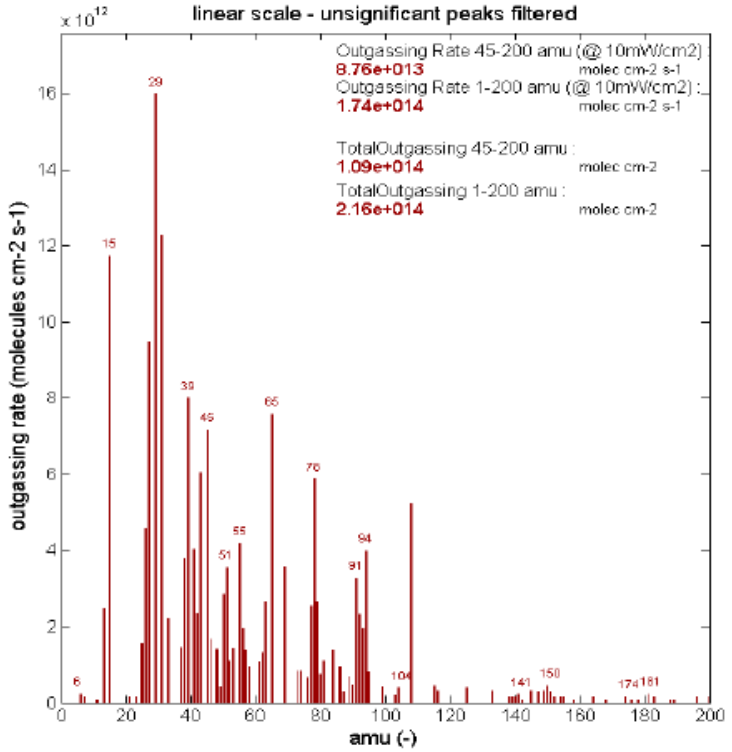
MET: 0.30NA, 0.68/0.36σ



Vertical profile was obtained at Hp26 on NCX7088A.

Outgassing data of NCX7088A

RGA data



Result

Pumping speed (l/s)		258
Power density (mW/cm2)		3.89
Outgassing rate 45-200amu (@10mW/cm2) (molecules cm-2 s-1) (calculated by Matlab routine)	< 5.00E+14	**8.76E+13** ok
max. individual peak in range 45-200	< 5.00E+13	**7.57E+12** ok

7.57E+12 < 5.00E+13 (target)

NCX7088A showed low ougtassing with RGA.

Outline

NEXL™
Challenging and Solution by x-layer

1. Introduction of UL for EUVL.

2. Design and performance of EUV specific Si-HM.
   - Photo speed enhancement
   - Resist profile control
   - Introduction of 1st generation Si-HM for EUV (NCX7088A).

3. **Introduction of Org.-UL for Ultra thin application (NCX1265).**

4. Conclusion

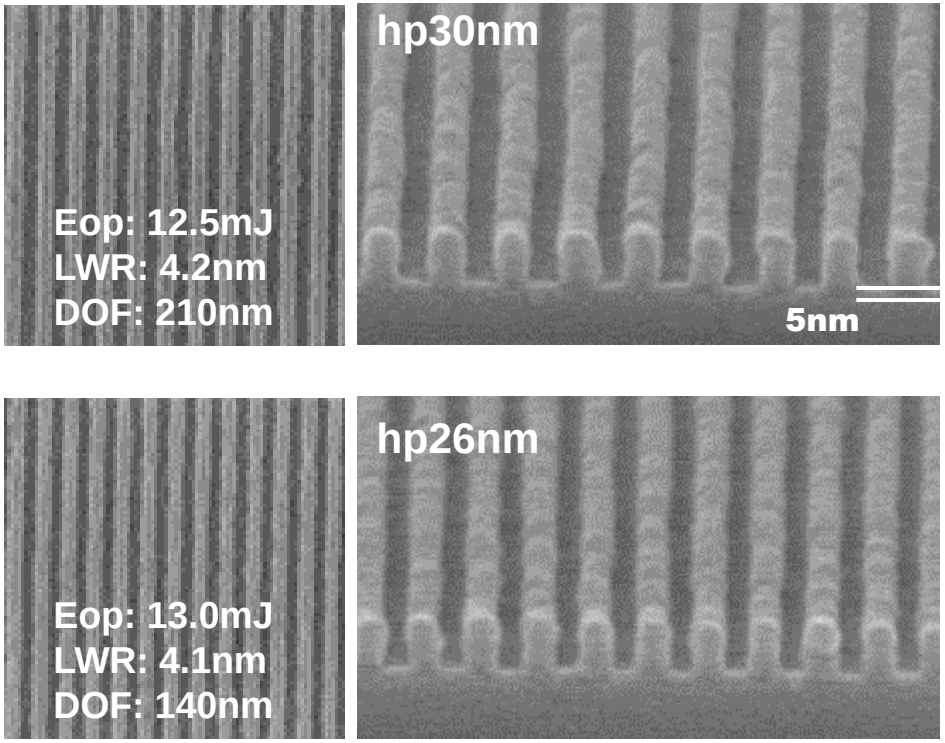
Org.-UL (NCX1265) Performance

5nm FTK

Lithography

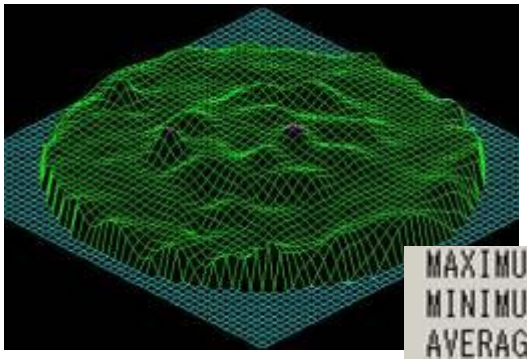
SEMATECH

MET: 0.30NA, 0.68/0.36σ

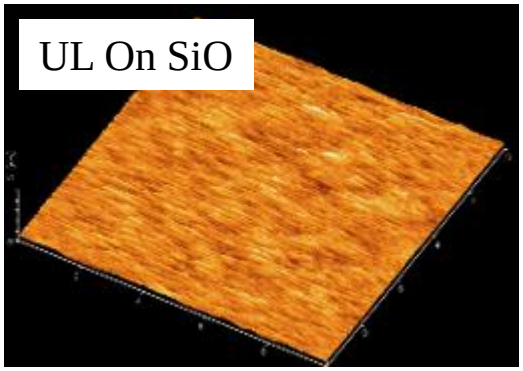


Good Lithographic performance

Coating performance



Good T.U.



No pin hole

Ra: 6.71E-02nm

Good coating performance

>> Poster presentation

Conclusion

1. EUV specific Si-HM and org.-UL have developed.

2. EUV absorption unit (Chromophore) or Radical generation unit could increase the acid generation efficiency at PR and UL interface and increase photo-Speed.

3. Resist Profile control is important to obtain low LWR and wide process window. Set up the good acidity valance is important to obtain the wide process window at over dose and under dose area.

4. NCI developed good candidate material of Si-HM (NCX7088A) and Org.-UL(NCX1265) for EUVL.

Thank you for your kind attention !!