EUV Workshop

June 15, 2017

P43

Novel EUV photoresist for sub-7nm node

Yoshi Hishiro

JSR Micro Inc.

Contents

- ***When Will EUV Come in Industry***
- ***JSR strategy for CAR improvement***
  - ***JSR Strategy for EUV CAR Improvement***
  - ***New Resist Development for CH and LS***
- ***Novel Material for EUV application***
  - ***Metal resist development***
  - ***Sensitizer Under layer***
- ***Summary***

When Will EUV Come in Industry?

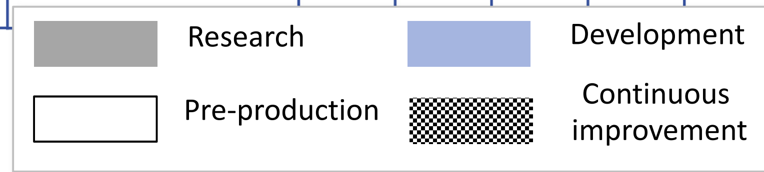
DRAM Critical and MPU Metal Level

Year		’15	’17	’19	’21
hp ~20nm	193nm QP				
20 ~14nm	193nm QP, EUV SP, DSA				
14 ~11nm	193nm QP, EUV DP, High NA EUV, DSA, Imprint				
11 ~7nm	EUV DP, High NA EUV, DSA, Imprint, 193nm OP				

Hole Type Pattern

ITRS2015

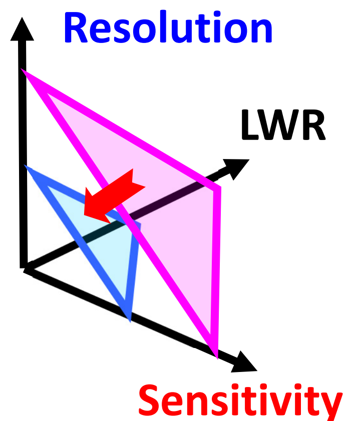
Year		’15	’17	’19	’21
hp ~54nm	193nm QP				
54 ~36nm	EUV SP, 193nm 4+ Exposure, Imprint, DSA				
36 ~26nm	High NA EUV, EUV DP, DSA, ML2, Imprint				
25nm~	TBD				



EUV is ready for high volume manufacturing. Need QA/QC and production. Continuous resist performance improvement is required.

JSR Strategy for EUV CAR Improvement

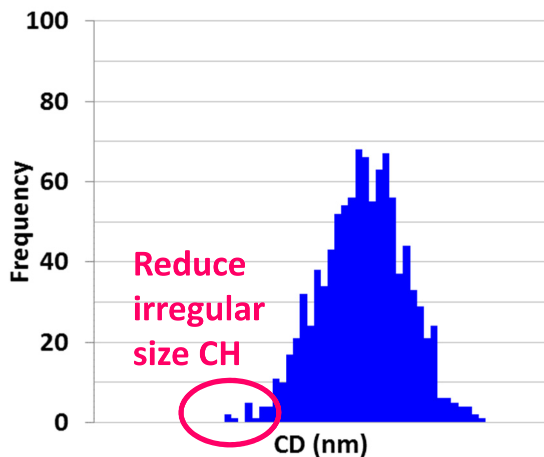
Requirements for EUV resist



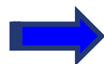
For EUV HVM
- Defectivity
- Process Window
- QA/QC
- Production

Strategy for Resist improvement

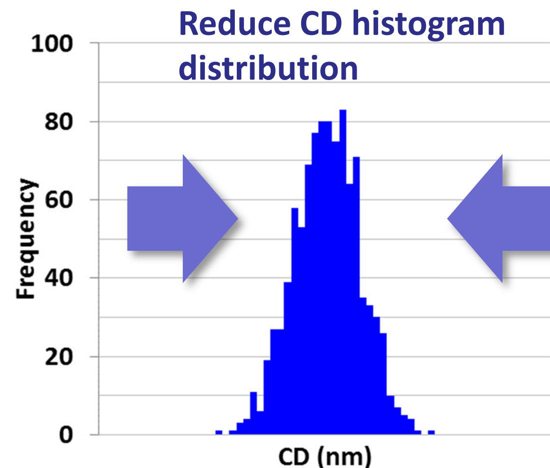
Item	Strategy
Resin	High Tg resin for acid diffusion control
PAG	Ultra short acid diffusion PAG
Additive	Efficient Quencher, Profile control



CH CD Distribution



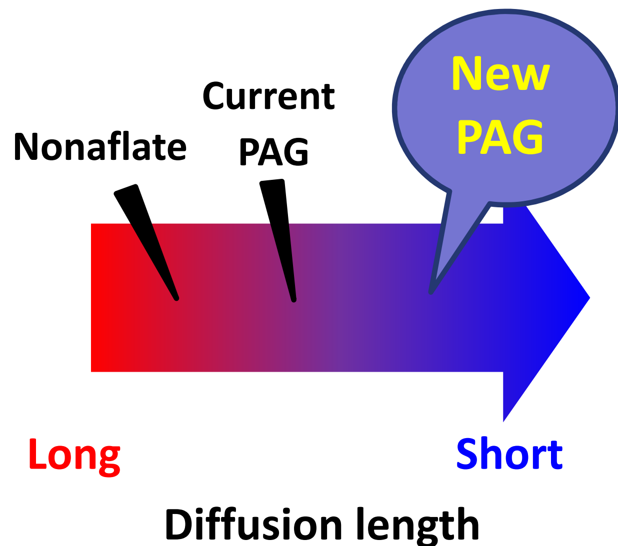
Reduced Resist Stochastic



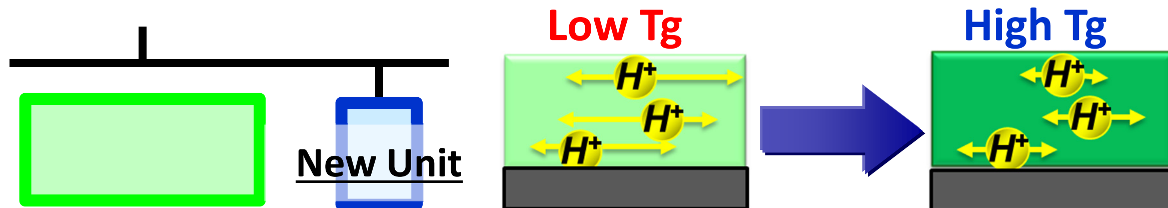
Reduce Stochastic is key for CAR improvement.

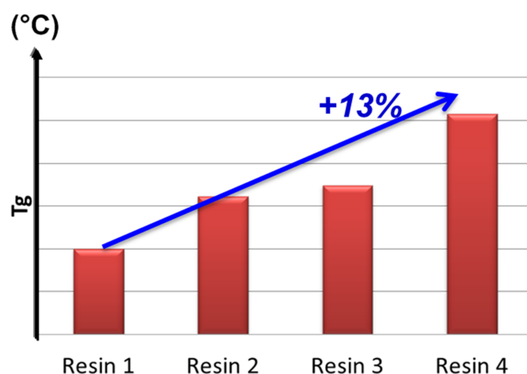
What is the best Material Design for CAR?

PAG Design



Resin Design





Berkeley MET, NA0.30

	22 nm HP	20 nm HP
Resin 1		
Resin 4		

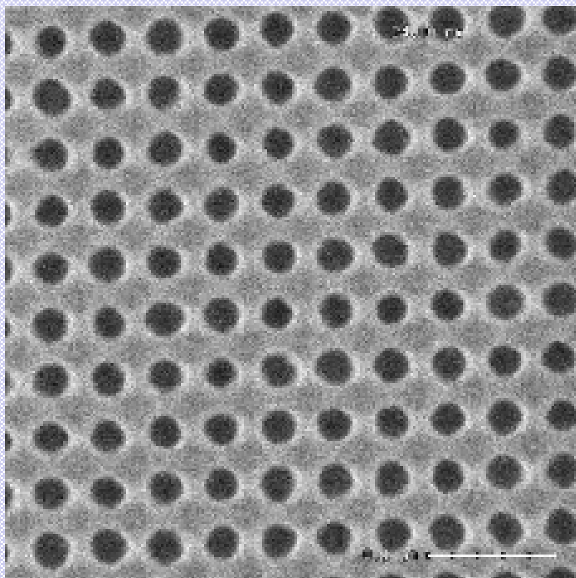
Detail was published in SPIE 2015(9422-24)

Resist Performance can be improved applied new chemicals.

New Resist Development for CH

@44nm Pitch CH

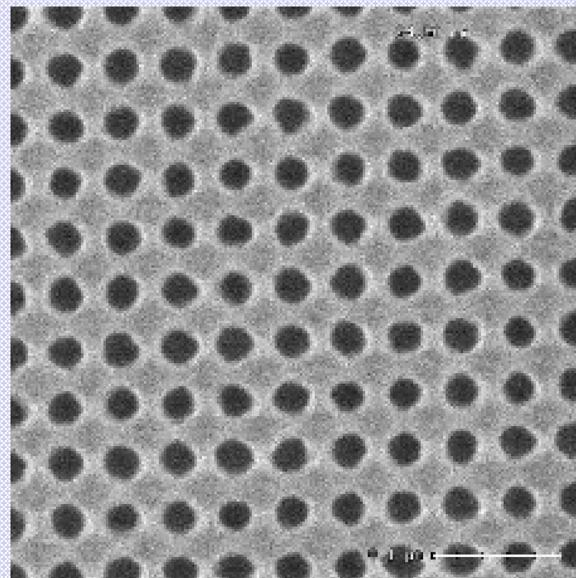
Current PAG/Polymer



Sensitivity: 36.8mJ/cm^2
LCDU: 3.46nm

26% Dose Reduction

New short ADL PAG with New high Tg polymer

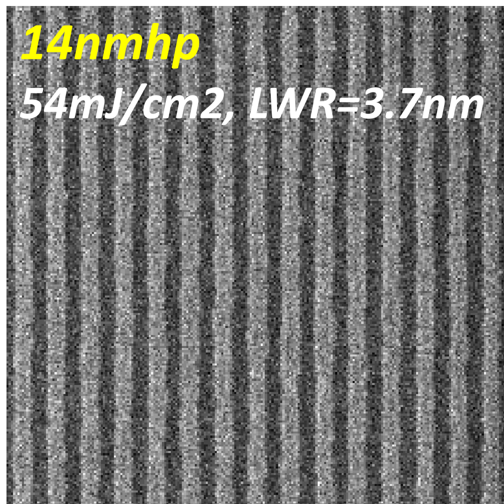


Sensitivity: 27.2mJ/cm^2
LCDU: 3.48nm

Exposed at NXE3300

Development of new PAG/Resin enables breakthrough performance.

LS Resist Development for Future Node

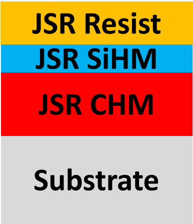


New short ADL PAG

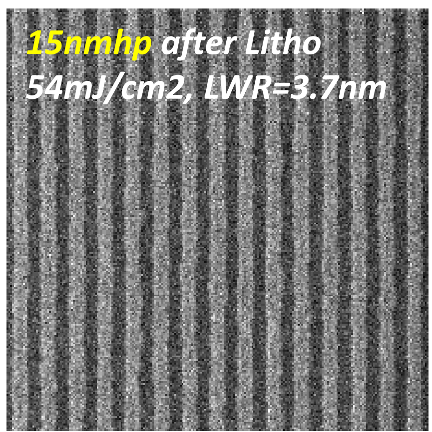
	49mJ	50mJ	51mJ	52mJ	53mJ	54mJ	55mJ	56mJ	57mJ
-60nm									
-40nm									
-20nm									
C.F									
+20nm									
+40nm									
+60nm									

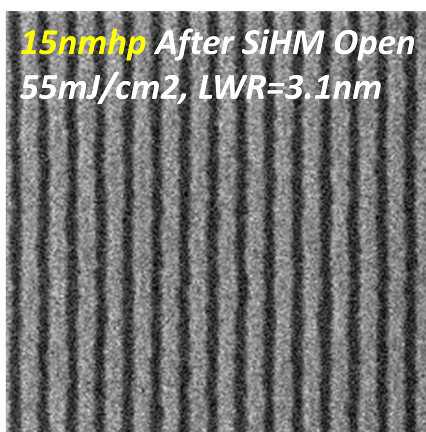
14nmhp LS can be resolved with reasonable LWR and wide process window.

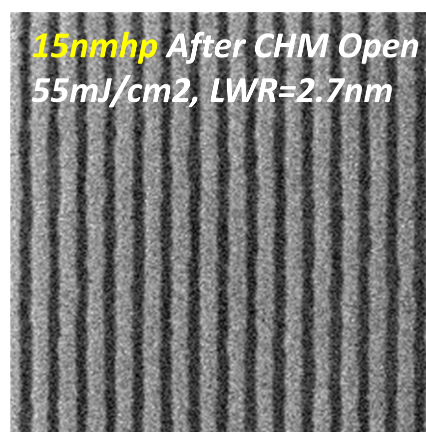
Etch Transfer with JSR Tri-layer Stack

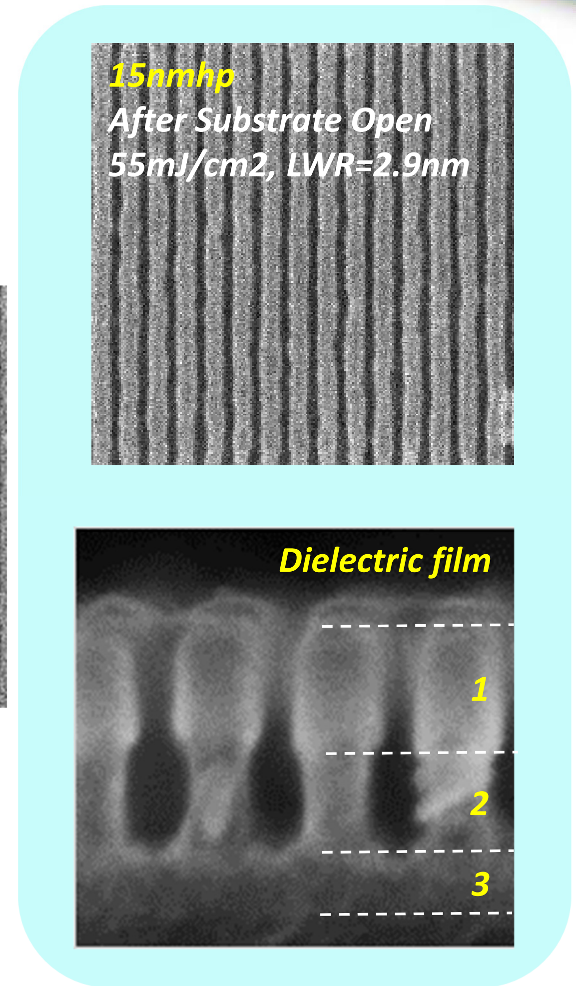


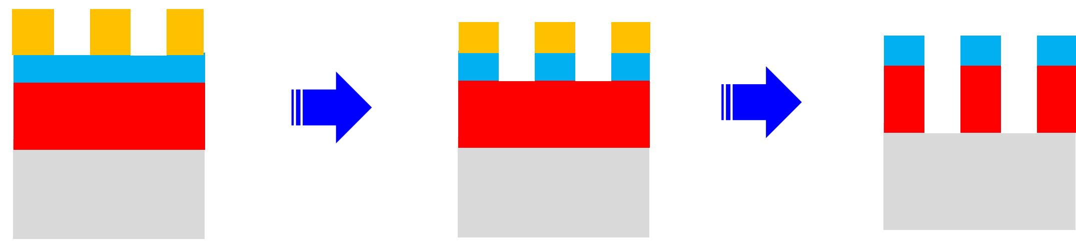
Challenging for 15nmhp LS Etch transfer to dielectric film using all JSR tri layer stack.









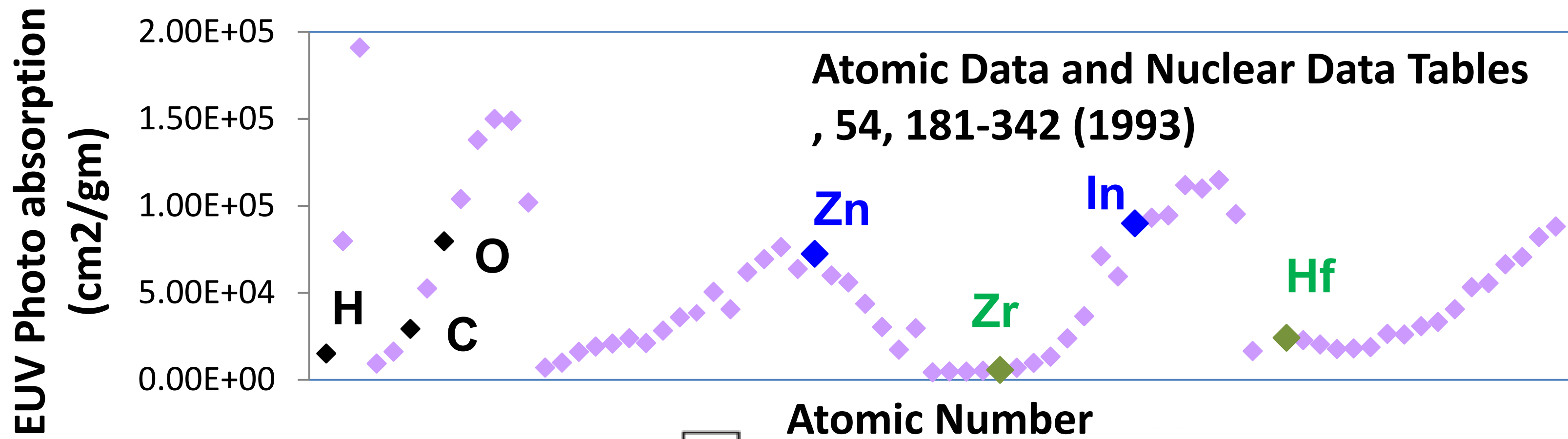


15nmhp LS Etch transfer have been succeed with JSR tri layer stack.

Contents

- *Requirement for EUV resist*
- *JSR strategy for CAR improvement*
  - *JSR Strategy for EUV CAR Improvement*
  - *New Resist Development for CH and LS*
- ***Novel Material for EUV application***
  - ***Metal resist development***
  - ***Sensitizer Under layer***
- ***Summary***

Motivation of Metal core application



1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57~71 La-Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89~103 Ac-Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn						

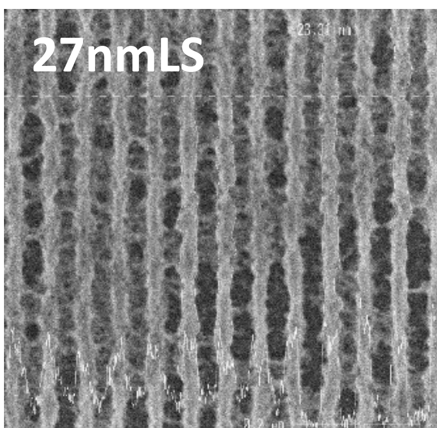
Potential Benefit of Metal resist

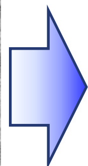
- **High sensitivity**
- **High etching selectivity**

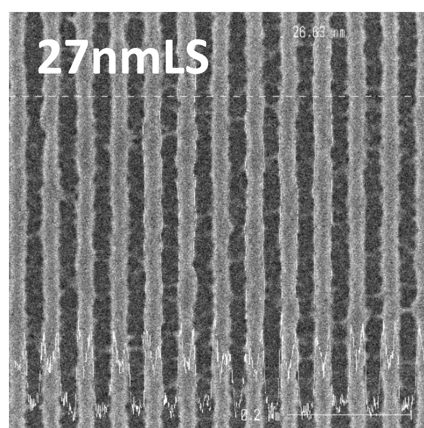
New metal species has been investigated using higher absorbance metals.

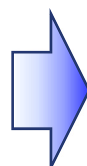
Metal resist Exposure result with NXE tools

Previous Metal NP System

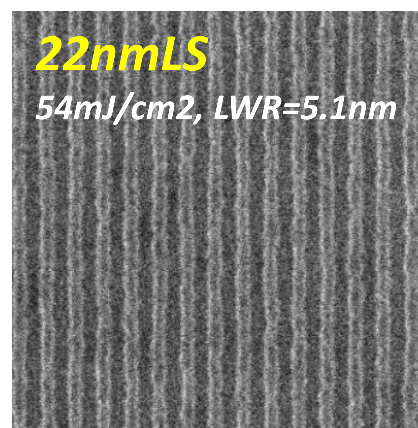


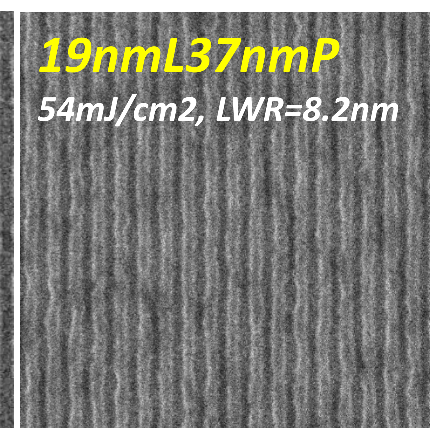






New Metal NP System





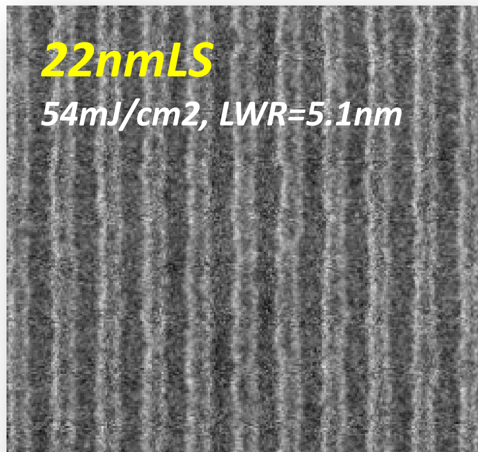
EUVLsymposium 2015
Session 5: EUV Resist 1
JSR Micro N.V.

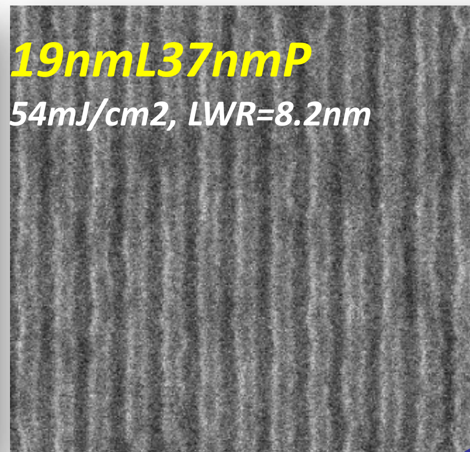
SPIE 2016
9776-977604
JSR-Cornell Univ.

SPIE 2017
NXE scanner with DGL membrane option to protect scanner optics.

Scum and resolution improvement was achieved by new Metal NP system.

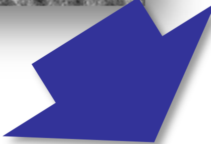
Metal resist Improvement after SPIE2017



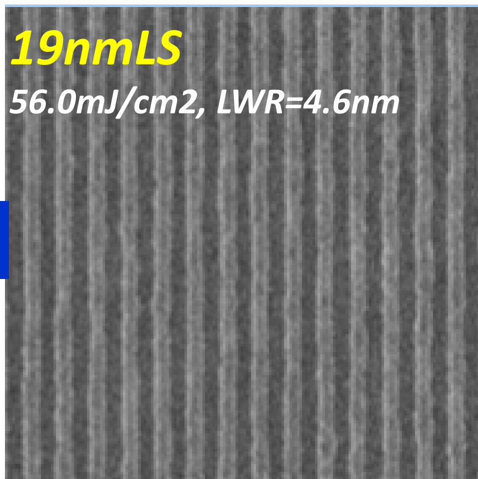


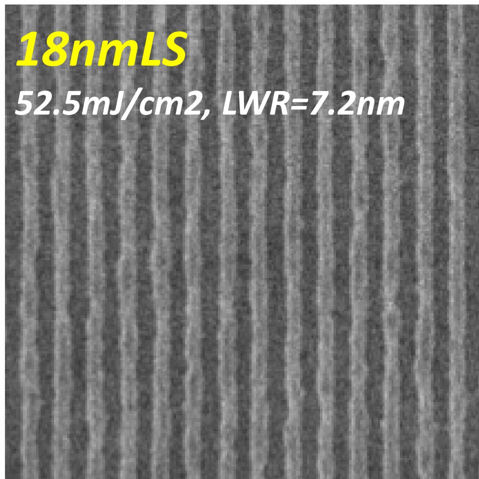
As of SPIE2017

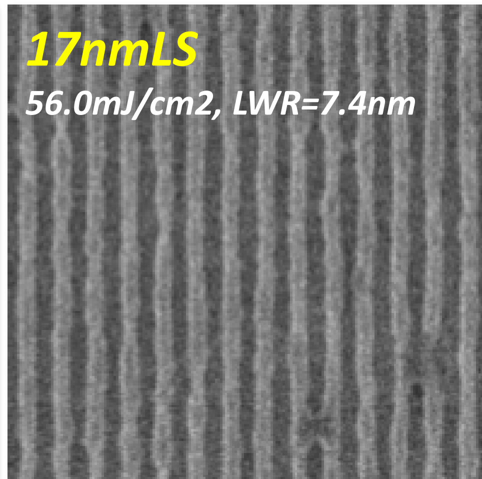
Material optimization



Current Best



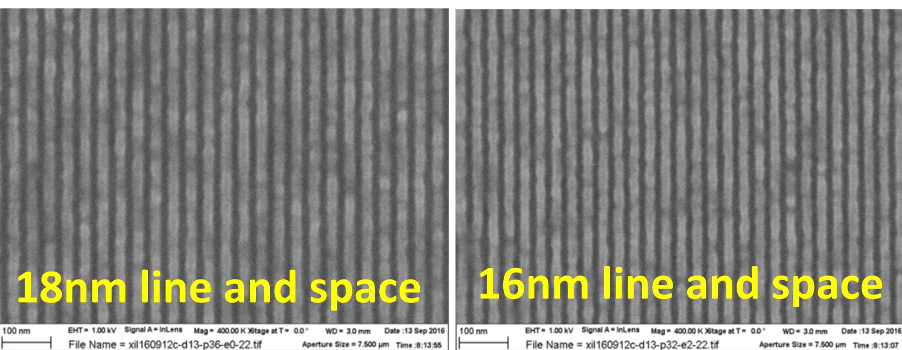




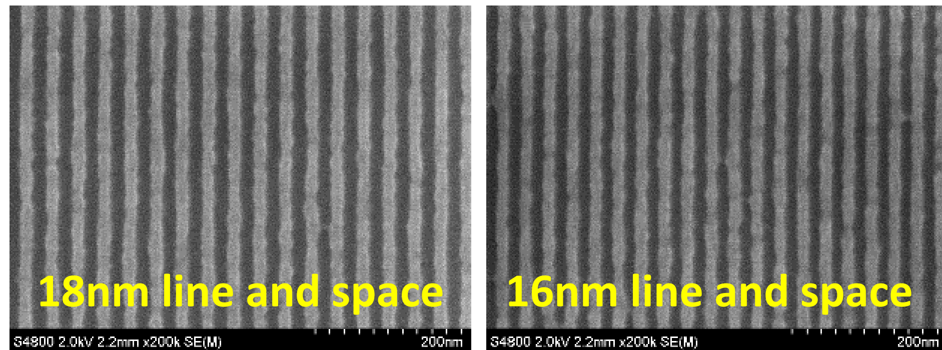
NXE scanner with DGL membrane option to protect scanner optics.

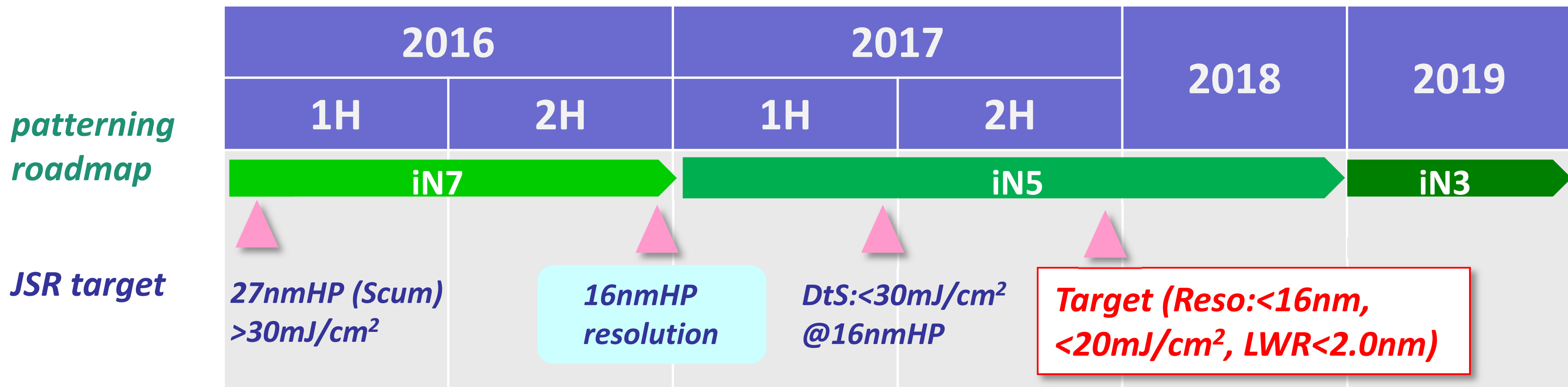
Ultimate Resolution of Metal resist

Ultimate resolution at PSI



Ultimate resolution at B-MET

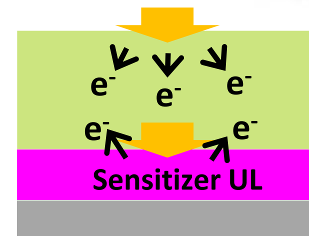




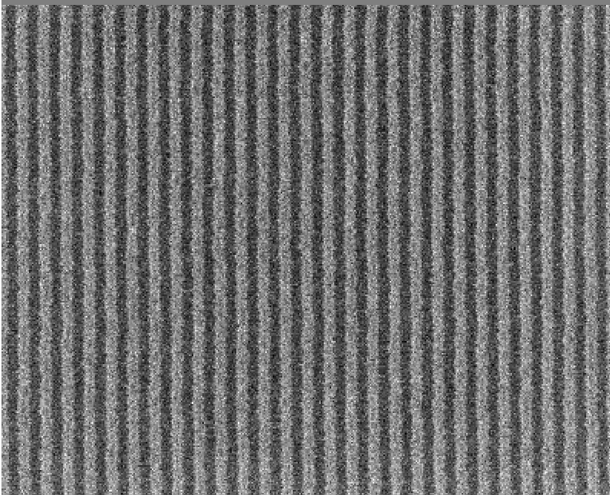
16nmhp resolution was achieved by new Metal NP system.

Sensitizer UL for LS application

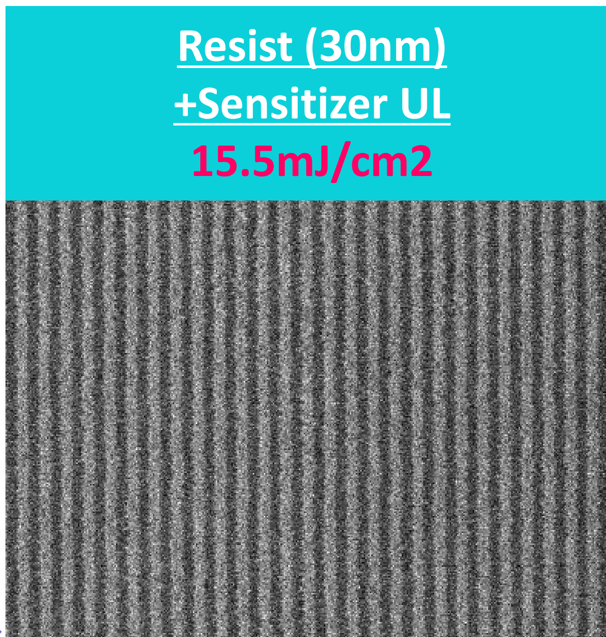
Resist sensitivity is improved by applying "Sensitizer Under layer"



Resist (30nm)+Organic UL
28.5mJ/cm2



Resist (30nm)
+Sensitizer UL
15.5mJ/cm2



Resist 30nm
+Sensitizer UL
High Temp bake, <9mJ/cm2

45% improve

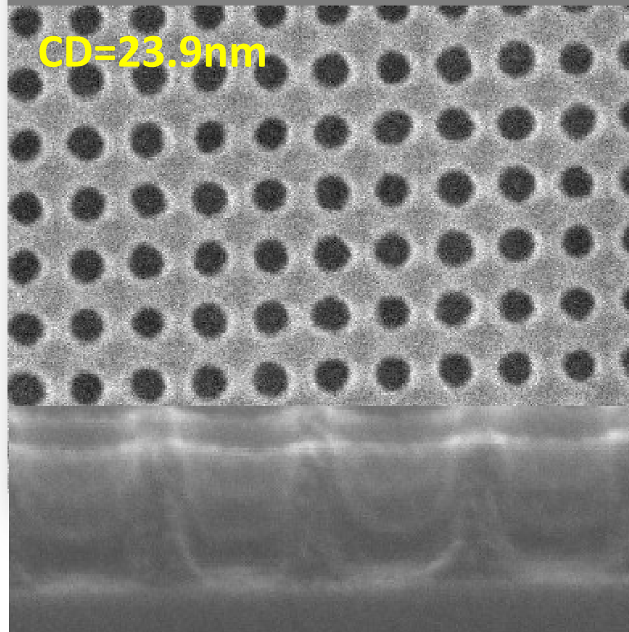
>70% improve

- **By changing process condition, sensitization ratio can be controlled.**
- **The possibility of 16nmLS@under 10mJ was observed.**

Sensitizer UL for CH and Etch Transfer Demo

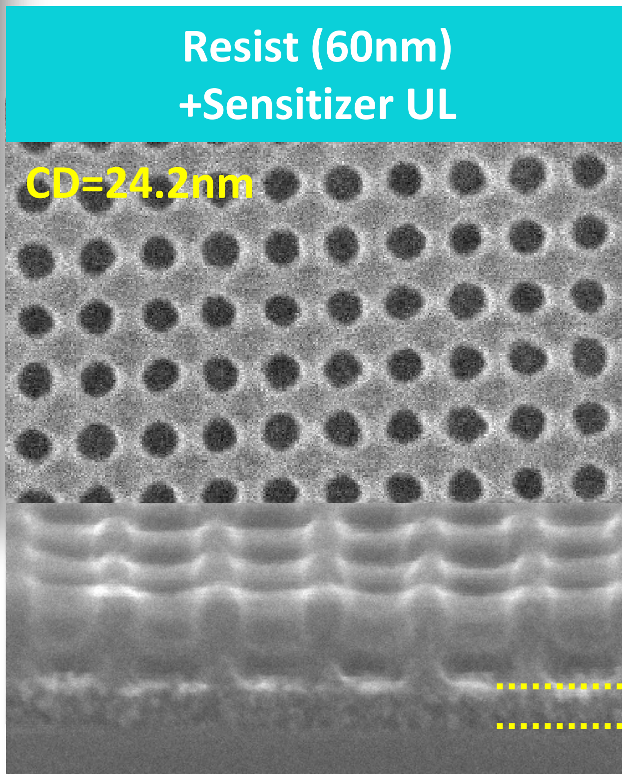
Resist sensitivity is improved by applying “Sensitizer Under layer” at 24nmCH44nmP pattern.

Resist (60nm) +Organic UL

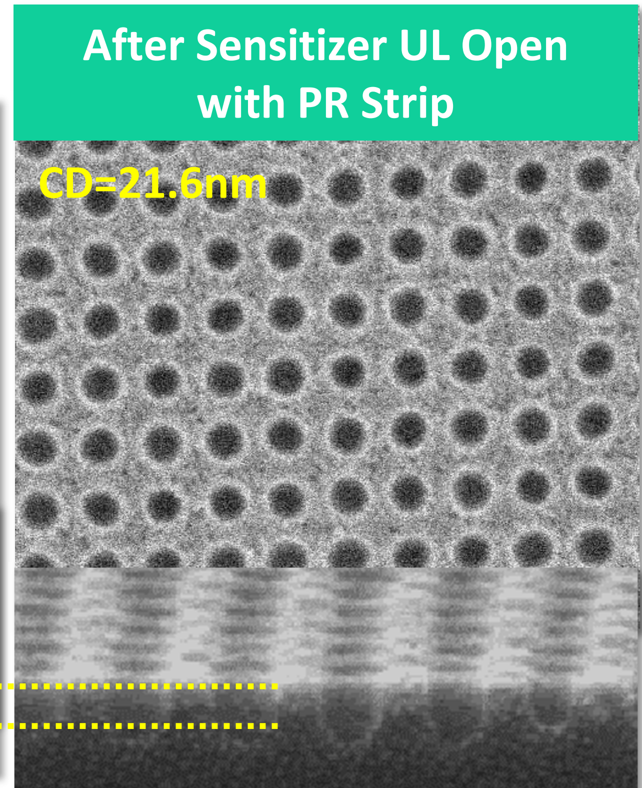


21% improve

Resist (60nm) +Sensitizer UL



After Sensitizer UL Open with PR Strip



Sensitivity 39.0mJ/cm2, LCDU=3.8nm

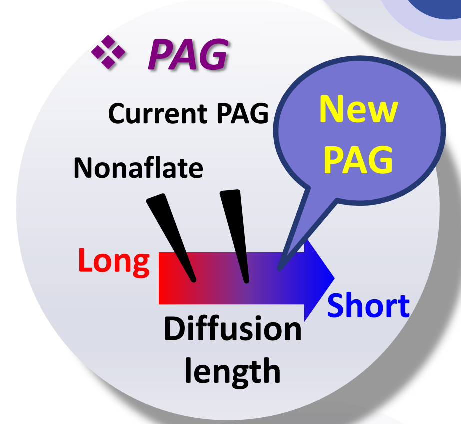
Sensitivity 30.8mJ/cm2, LCDU 3.9nm

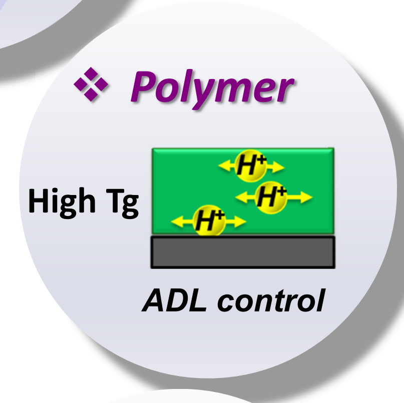
Sensitivity 30.8mJ/cm2, LCDU 4.0nm

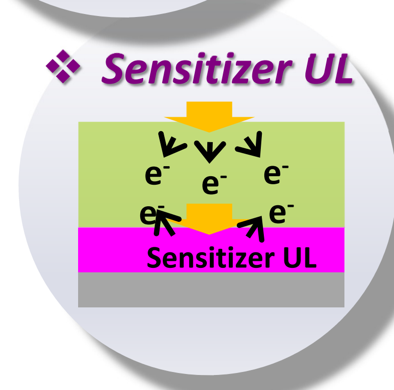
Sensitization was confirmed on CH and etch transfer have been demonstrated.

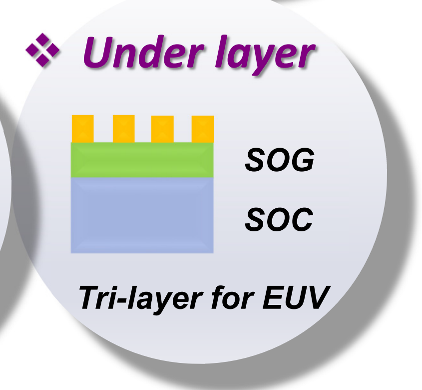
Summary

- ✓ ***Material development for breakthrough CAR performance***
  - *Acid diffusion control by high Tg resin & short acid diffusion PAG*
  - *CH : Well balanced sensitivity, LCDU and resolution. Ready for HVM.*
  - *LS : Promising resolution with wide process window and etch transfer.*
- ✓ ***New metal resist development***
  - *16nmhp resolution was achieved by new Metal NP system.*
- ✓ ***Sensitizer UL***
  - *The possibility of 16nmLS@under 10mJ was observed.*









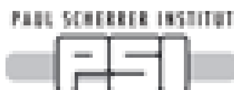
Acknowledgement

Gratefully thank to,

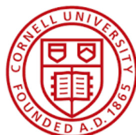
for the close collaboration and discussion

for the close collaboration and discussion

for the exposure support on MET

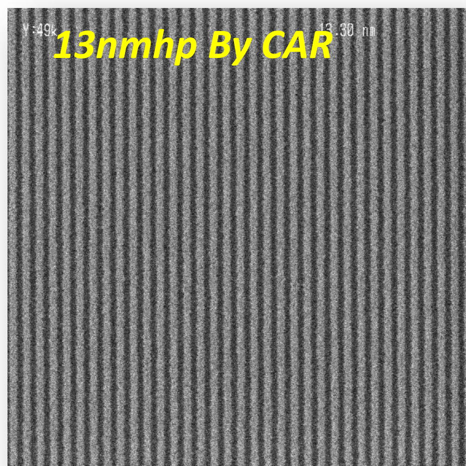


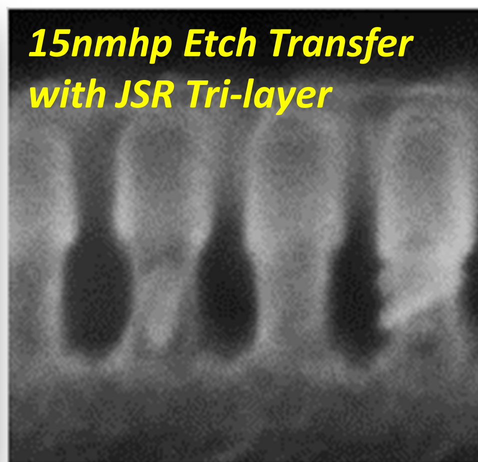
for the exposure support

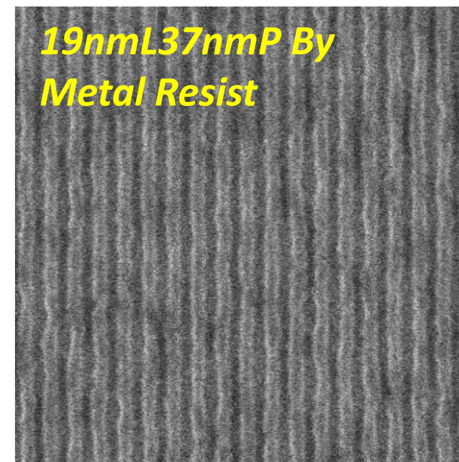


for Novel EUV Resist Development Collaboration

Thank you for your attention !!







Materials Innovation

With chemistry, we can.