JSR SEMICONDUCTOR MATERIALS LABORATORY

Novel EUV resist materials and EUV resist defects

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Contents

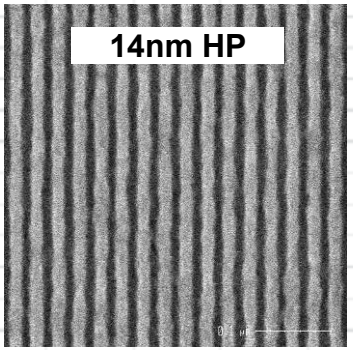
- ✓ *Challenge of EUV Resist for 16nmHP*
- ✓ *Key factor of EUV Resist Improvement*
- ✓ *Defect Improvement*
- ✓ *Achievement of EUV Resist*
- ✓ *Summary*

When will EUV come in Industry?

ITRS2012 *Lithography TWG DRAM and MPU Potential Solutions*

	First Year of IC Production	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	DRAM ½ pitch (nm) (contacted)	36	32	28	25	23	20.0	17.9	15.9	14.2	12.6	11.3	10.0	8.9	8.0	7.1	6.3
	MPU/ASIC Metal 1 1/2 pitch (nm)	38	32	27	24	21	18.9	16.9	15.0	13.4	11.9	10.6	9.5	8.4	7.5	7.5	7.5
45	193nm Imm																
32	193 nm DP																
22	EUV 193nm MP ML2 (MPU)	Narrow Options															
16	EUV 193nm MP ML2 DSA + Litho Imprint				Narrow Options												
11	EUV higher NA / EUV + DP ML2 DSA + Litho EUV (new wavelength) Imprint Innovation							Narrow Options									

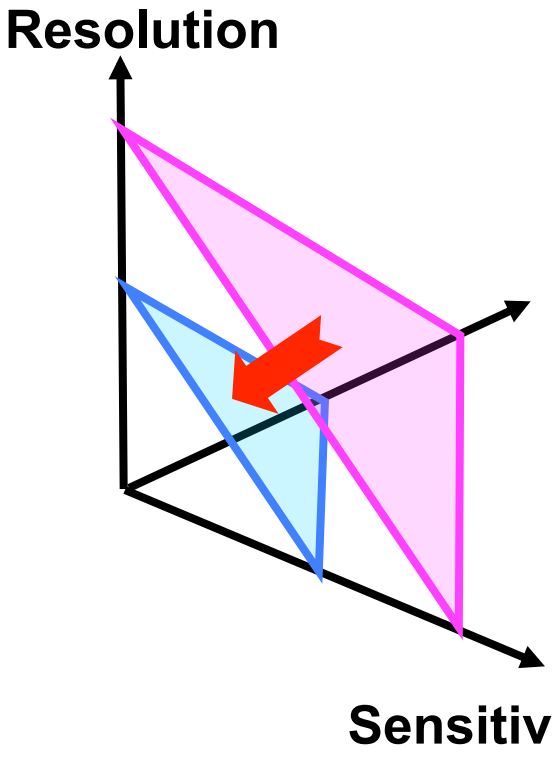
MPU / DRAM time line



CAR resist on NXE3300
SPIE2013 ASML

- ***EUV is delayed, likely adopted sub 14 nm node.***
- ***The higher resolution will be required for EUV resist.***

EUV Resist Requirement & Challenges



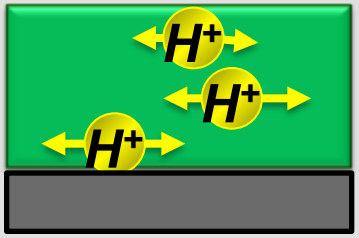
- ✓ *Low Outgassing*
- ✓ *Suppression of OOB influence*
- ✓ *Defectivity*

etc…

- *Simultaneous improvement in Resolution, LWR and Sensitivity (RLS) is required.*
- *Good defectivity is required for HVM.*

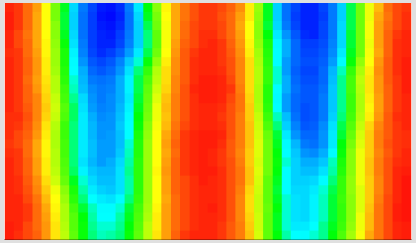
Key Factors of EUV Resist Improvement

Diffusion Control of PAG Acid

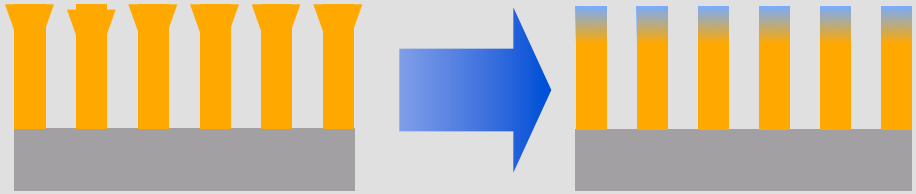


- Polymer Tg
- New PAG…

High Dissolution Contrast

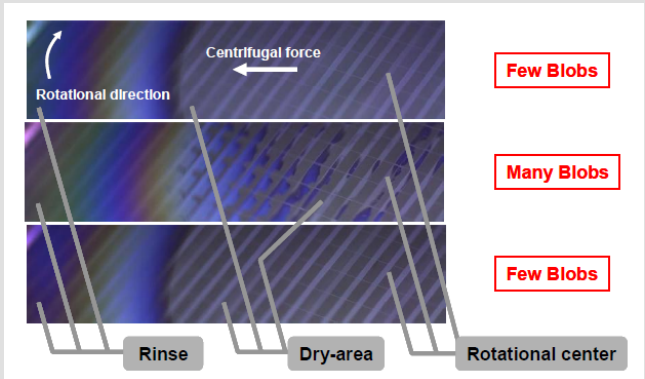


Good Pattern Profile



- Resin solubility
- Profile controller

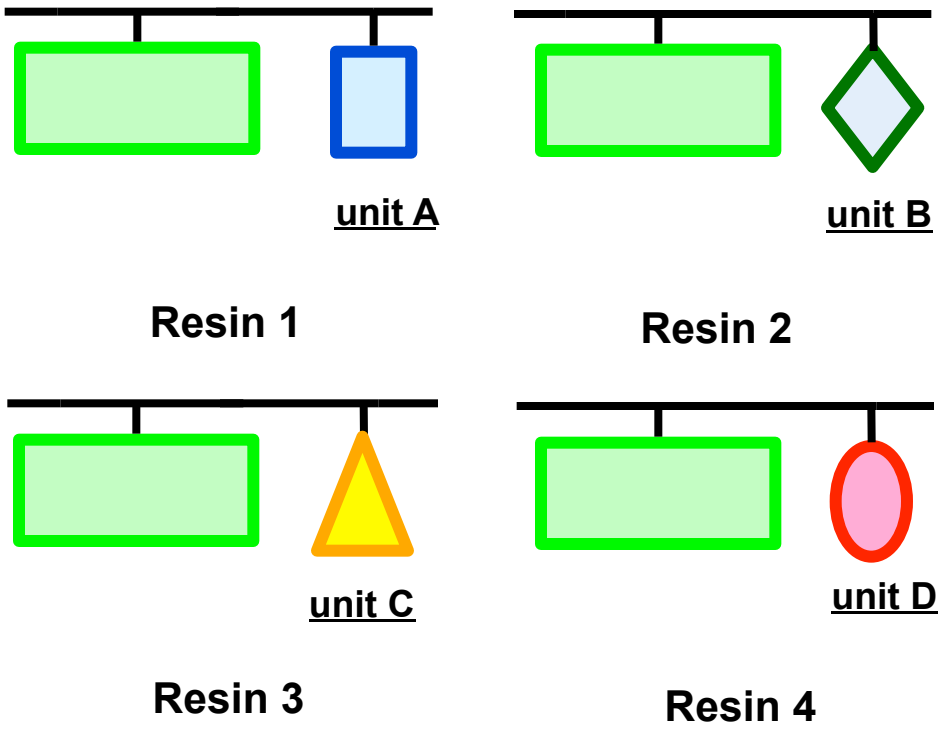
Good Developer/Rinse Wettability

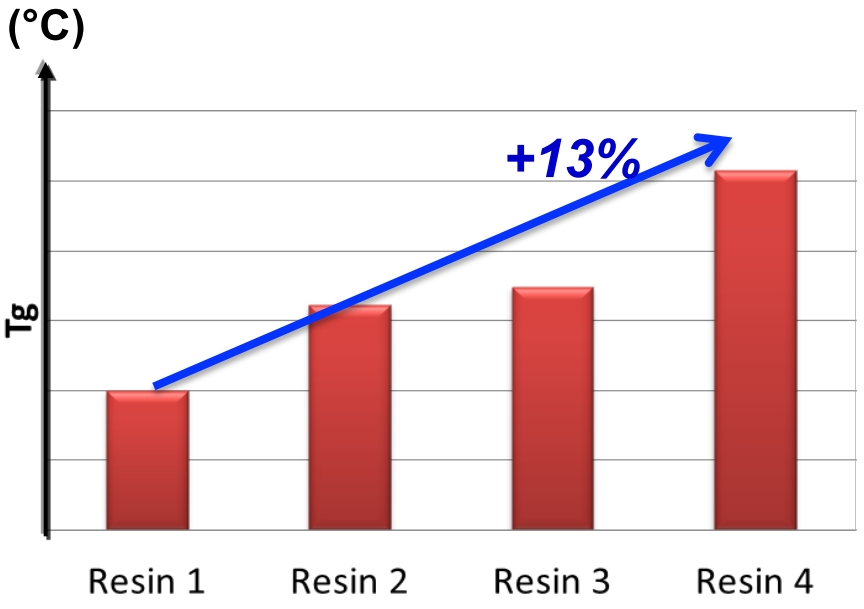


M. Harumoto et. Al. SOKUDO , SPIE 2013, 79692G-1

- Resist hydrophilicity

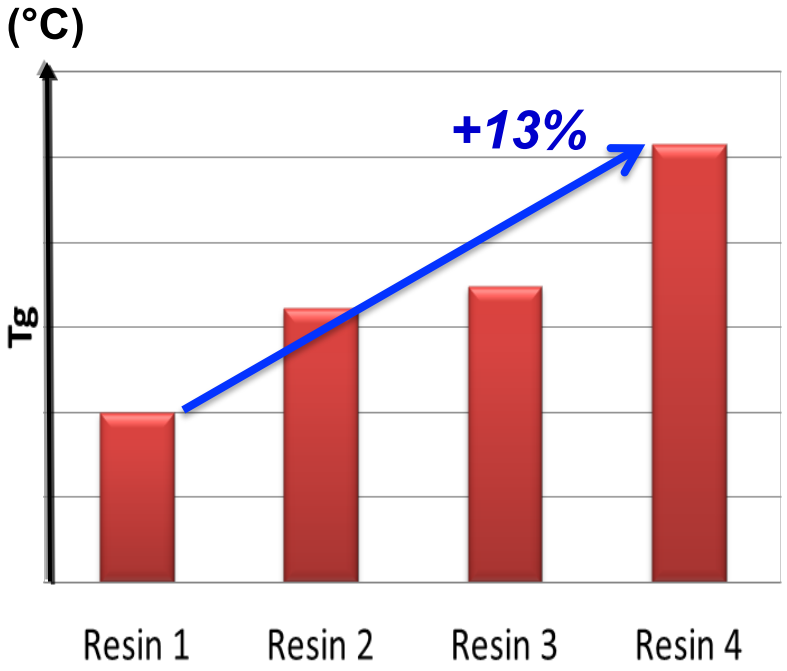
Acid Diffusion Control by Resin





- *JSR developed new monomers to increase resin glass transition temperature (Tg).*
- *Resin with higher Tg was developed to control acid diffusion length.*

Relationship between Tg and Resolution

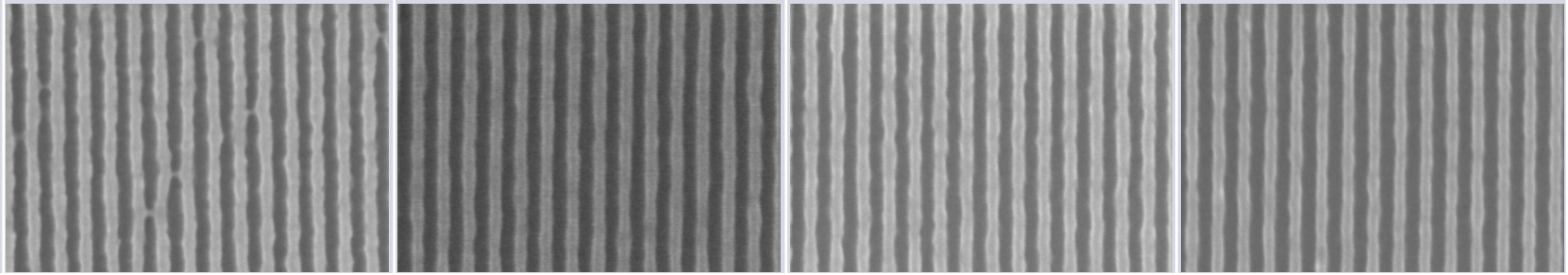


	22 nm HP	20 nm HP	19 nm HP
Resin 1			
Resin 2			
Resin 3			
Resin 4			

LBNL MET NA0.3 Dipole

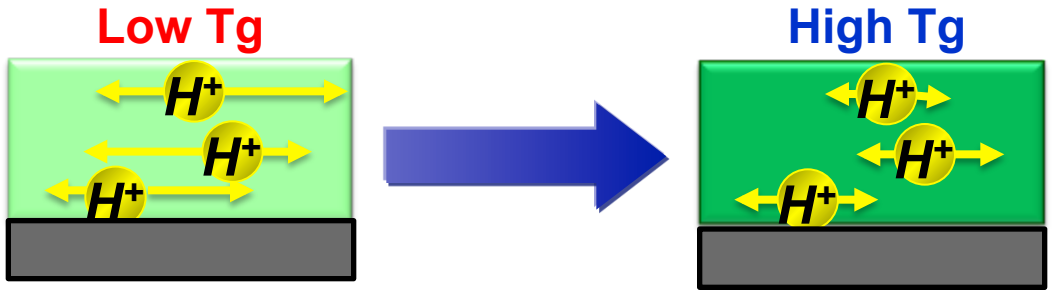
High Tg resin showed better resolution, but saturation was observed. However…

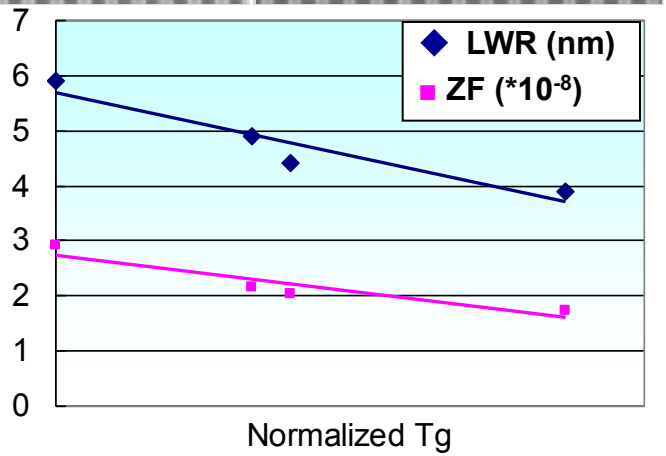
Relationship between Tg and LWR, Z-factor

	Resin1	Resin2	Resin3	Resin4
Tg*	100	106	107	113
LWR	5.9 nm	4.9 nm	4.4 nm	3.9 nm
Z-factor	2.93E-08	2.17E-08	2.04E-08	1.74E-08
SEM image (22nmHP)				

Z-factor = $(\text{Resolution})^3$ X $(\text{LER})^2$ X (Sensitivity)

T. Wallow et. Al. SPIE 2008, 69211F





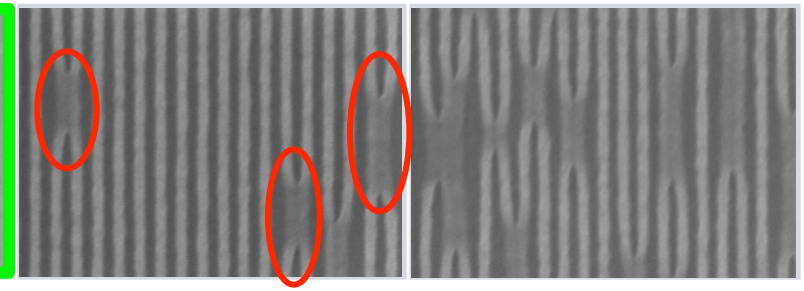
- ***LWR & Z factor are linearly improved by the increase of resin Tg.***
- ***It proved well-suppressed acid diffusion, potentially better resolution.***

Pattern Collapse & Profile Control

Standard resist

CD(nm)/LWR(nm)

HP	20nm	19nm	18nm	17nm
46.5mJ	19.2/4.1	18.9/3.6		



LBNL MET NA0.3, Pseudo-PSM

Pattern Collapse

- ***Resolution is limited by pattern collapse.***
- ***Pattern collapse mitigation requires profile control.***

Effect of Profile Control Agent

Normal resist

CD(nm)/LWR(nm)

HP	20nm	19nm	18nm	17nm
46.5mJ	19.2/4.1	18.9/3.6		

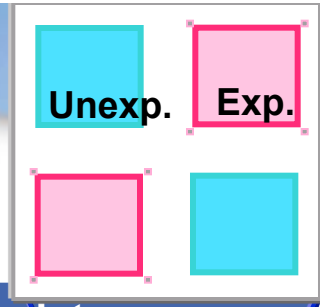
Resist with Profile controller

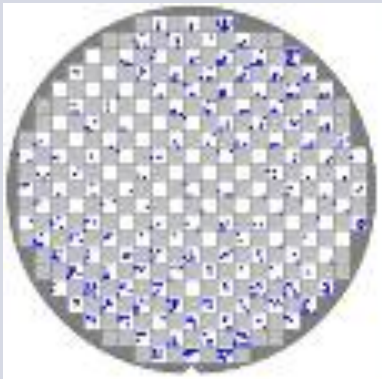
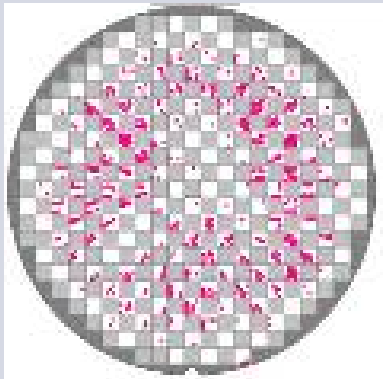
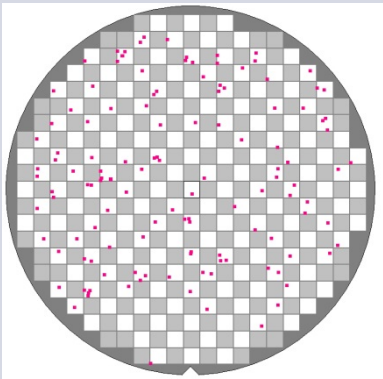
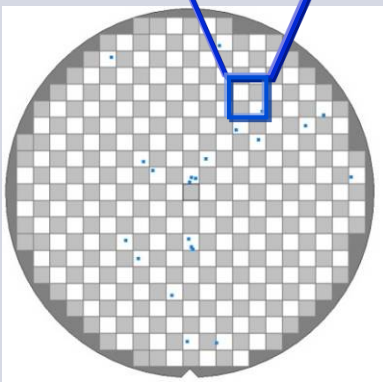
HP	20nm	19nm	18nm	17nm
46.5mJ	19.9/3.4	19.0/3.4	17.8/3.7	16.7/3.9

LBNL MET NA0.3, Pseudo-PSM

- *Profile control agent makes resist surface more soluble.*
- *It improves pattern collapse and therefore resolution limit.*

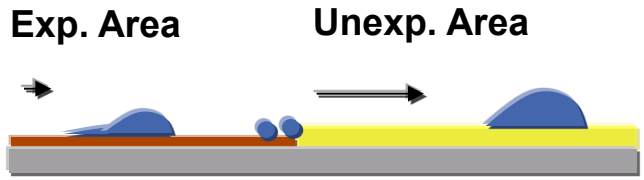
Resist Defectivity Improvement



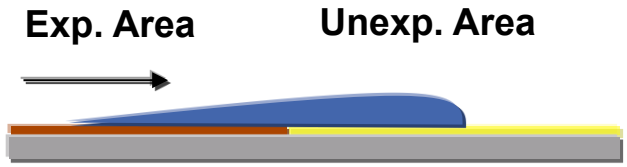
	Normal Resist		Hydrophilic Resist	
Water CA*	—	100	—	48
	Exposed Area	Unexposed Area	Exposed Area	Unexposed Area
Wafer map				
Defect	14.0 /cm^2	18.2 /cm^2	**1.8 /cm^2**	**0.4 /cm^2**

*Normalized value

●Normal Resist



●Hydrophilic Resist

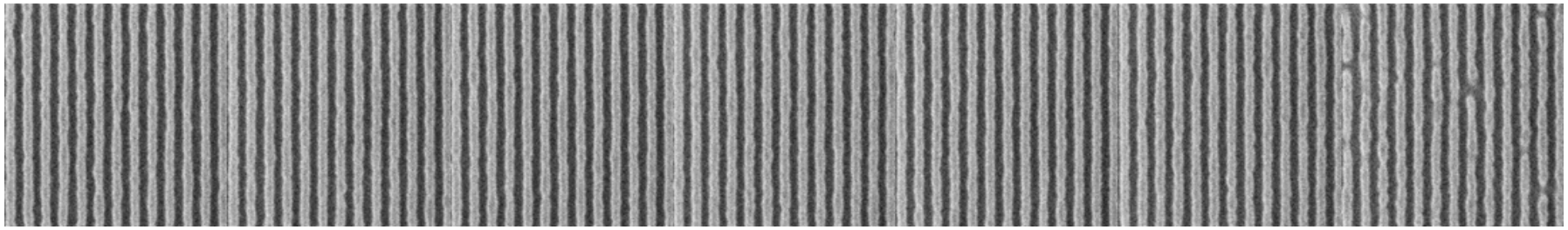


By reducing resist hydrophobicity, good defectivity could be achieved.

Achievement of our EUV resist

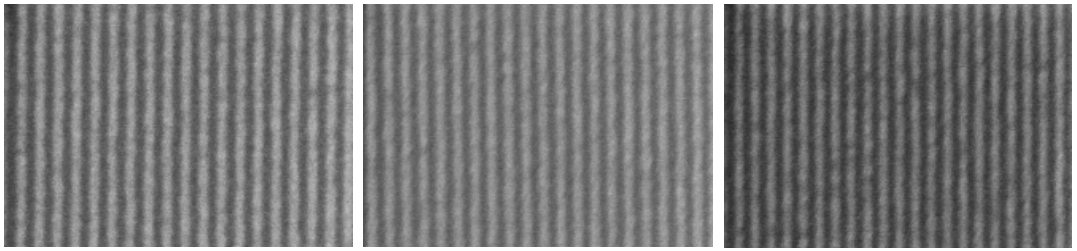
18 nm LS DOF on NXE3100 Dipole 60

-120nm -80nm -40nm BF +40nm +80nm +120nm

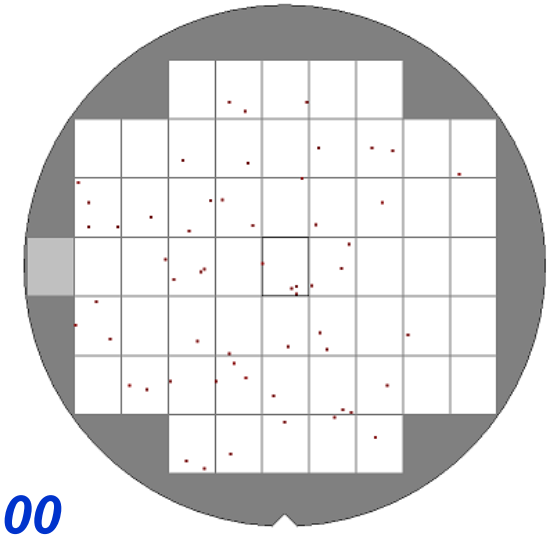


Ultimate Resolution on BMET

17nm hp 16nm hp 15nm hp



32 nm LS Defectivity on NXE3100



Defect : 0.17/cm^2

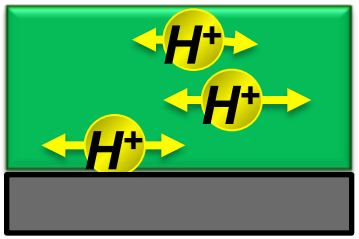
- ***Excellent PW for 18 nm LS with NXE3100***
- ***Ultimate resolution of 15 nm hp with B-MET***
- ***Good defect density for 32 nm LS on NXE3100***
- ***JSR makes more progress for the future!***

Summary

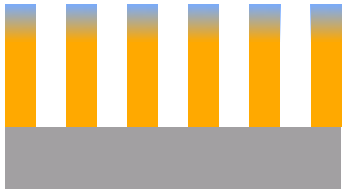
- ✓ ***EUV Resist Development Strategy***
  - ***High Tg resin improves Resolution and LWR.***
  - ***Profile control is important for resolution.***

- ✓ ***Defectivity Improvement***
  - ***By controlling resist hydrophobicity, defectivity gets better.***

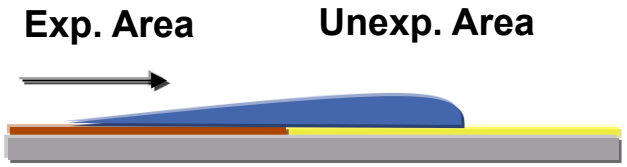
- ✓ ***EUV Resist's Challenge for HVM***
  - ***Excellent PW, defectivity were achieved. We continue to improve more resolution.***



・High Tg resin



・Profile Control



・Resist wettability

Acknowledgement

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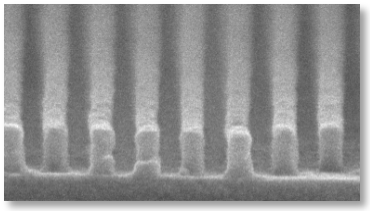
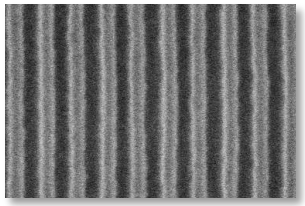
- Yan Thouroude / SCREEN
- Todd R. Younkin
- Erik Verduijn
- Norihiko Sugie / EIDEC

Thank you for your attention !!

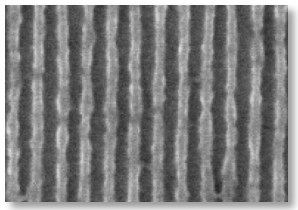
2007
40 nm LS, ArFi



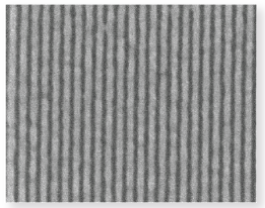
2008
26 nm LS, ArFi DP



2010
19 nm LS, EUV



2013
14 nm LS, EUV



Materials Innovation

JSR