Accelerating the next technology revolution

EUV Resist Patterning Results for 22 nm HP and Smaller

- EUV Resist Cycles of Learning

Kyoungyong Cho, Karen Petrillo
Dominic Ashworth, Liping Ren
George Huang, Warren Montgomery

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SEMATECH's RMDC helping to reach ultimate goal for 22nm and beyond

- Develop litho solutions through access to advanced imaging
  - EUV Micro Exposure Tools (MET): 3-5 years before full field tool availability
  - EUV Alpha Demo Tool (ADT): 1 of 2 in the world

- Our strategy continues as we plan for the 11nm node and beyond
  - EUV MET 0.5 NA upgrade ready by 2012

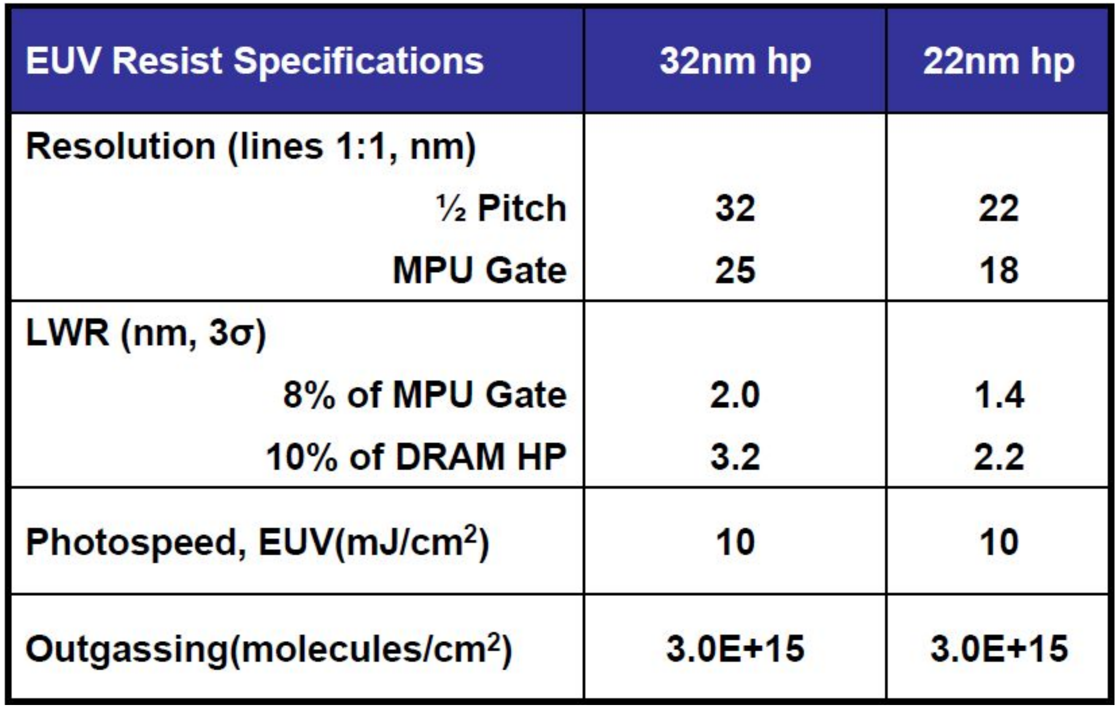
SEMATECH ADT (0.25 NA)

SEMATECH Albany MET (0.3 NA)

SEMATECH Berkeley MET (0.3 NA)

Objectives : EUV Resist Patterning Learning

- Evaluate EUV resist samples with well defined protocols and specification targets.
- Focus on resolution, photospeed, and LWR for 26 nm and LWR targeted to 22 nm.



EUV Resist Specifications	32nm hp	22nm hp
Resolution (lines 1:1, nm)		
½ Pitch	32	22
MPU Gate	25	18
LWR (nm, 3σ)		
8% of MPU Gate	2.0	1.4
10% of DRAM HP	3.2	2.2
Photospeed, EUV(mJ/cm^2)	10	10
Outgassing(molecules/cm^2)	3.0E+15	3.0E+15

Assumptions: Photospeed target is for 1:1 lines and spaces.
Outgassing specification is for 35-200 AMU excluding 44 AMU.

EUV Resist Cycles Of Learning

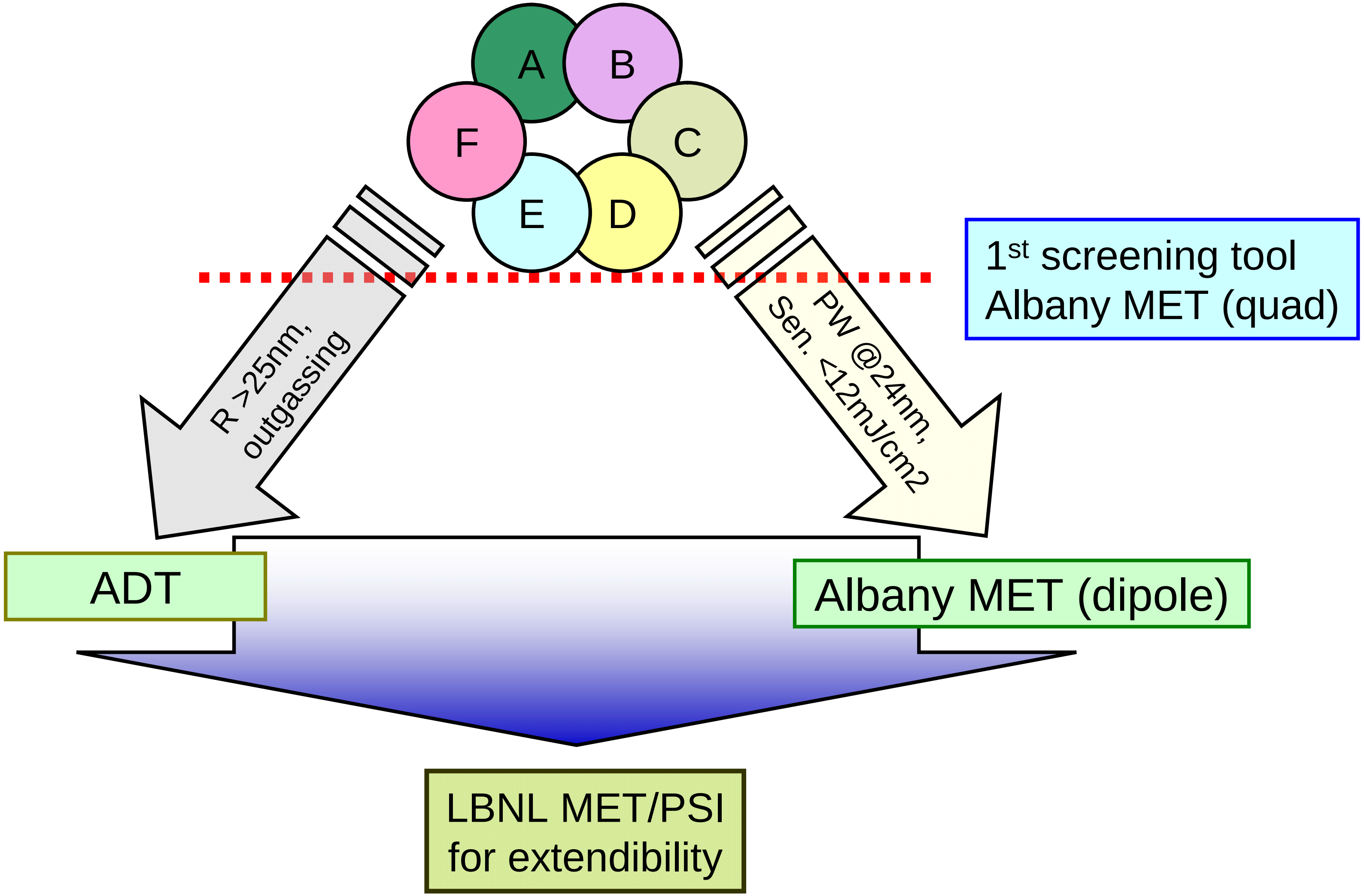
- Use Albany MET as a baseline tool for EUV resist cycles of learning in 2010

- Characterize the progress of EUV resist L/S and contact hole performance bi-monthly.

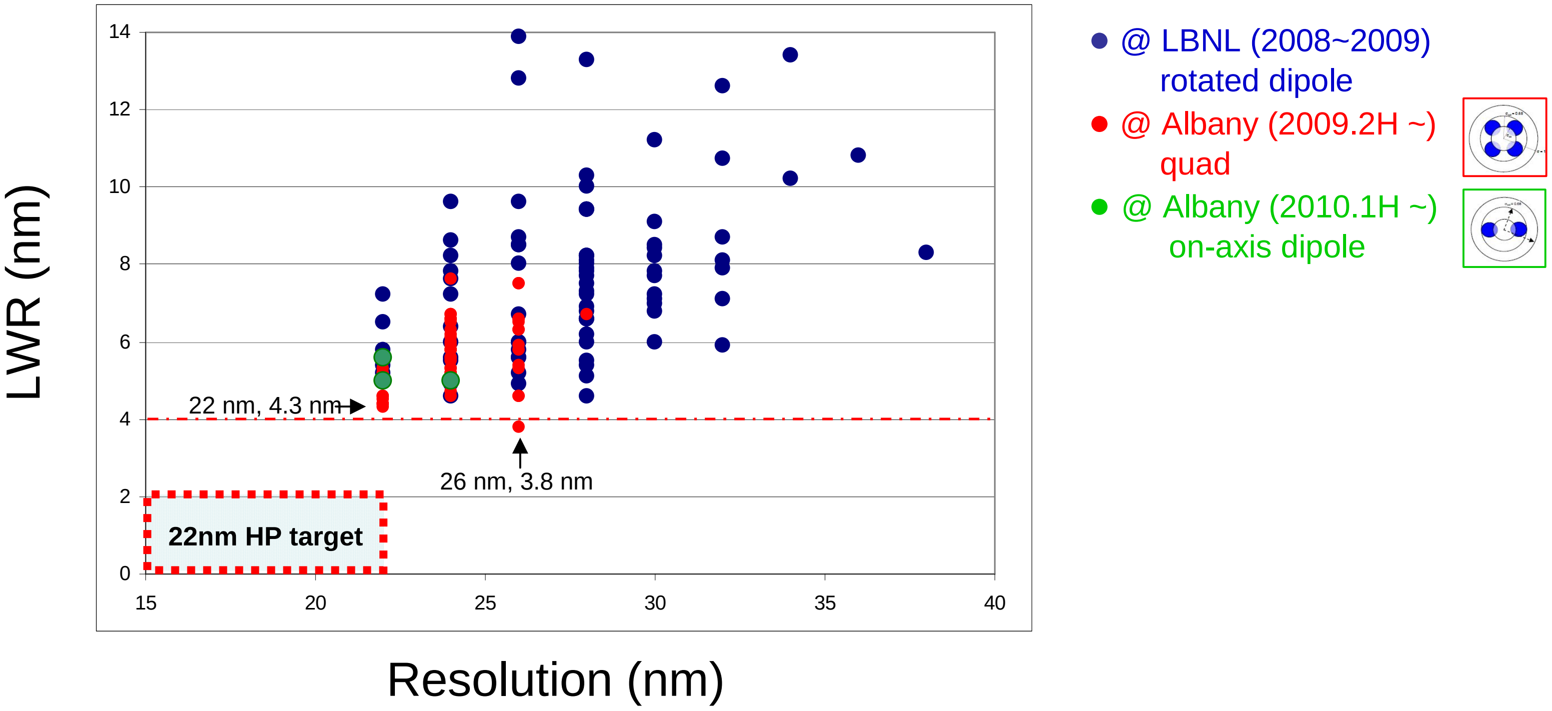
- Use the following process conditions:
  - Quadrupole illumination for L/S, annular for CNT
  - Resist thickness: 40 nm for L/S, 80 nm for CNT
  - Mask: Standard a-MET mask

- Image selected candidates on ADT and using on-axis dipole on MET.

EUV Resist Characterization Procedure



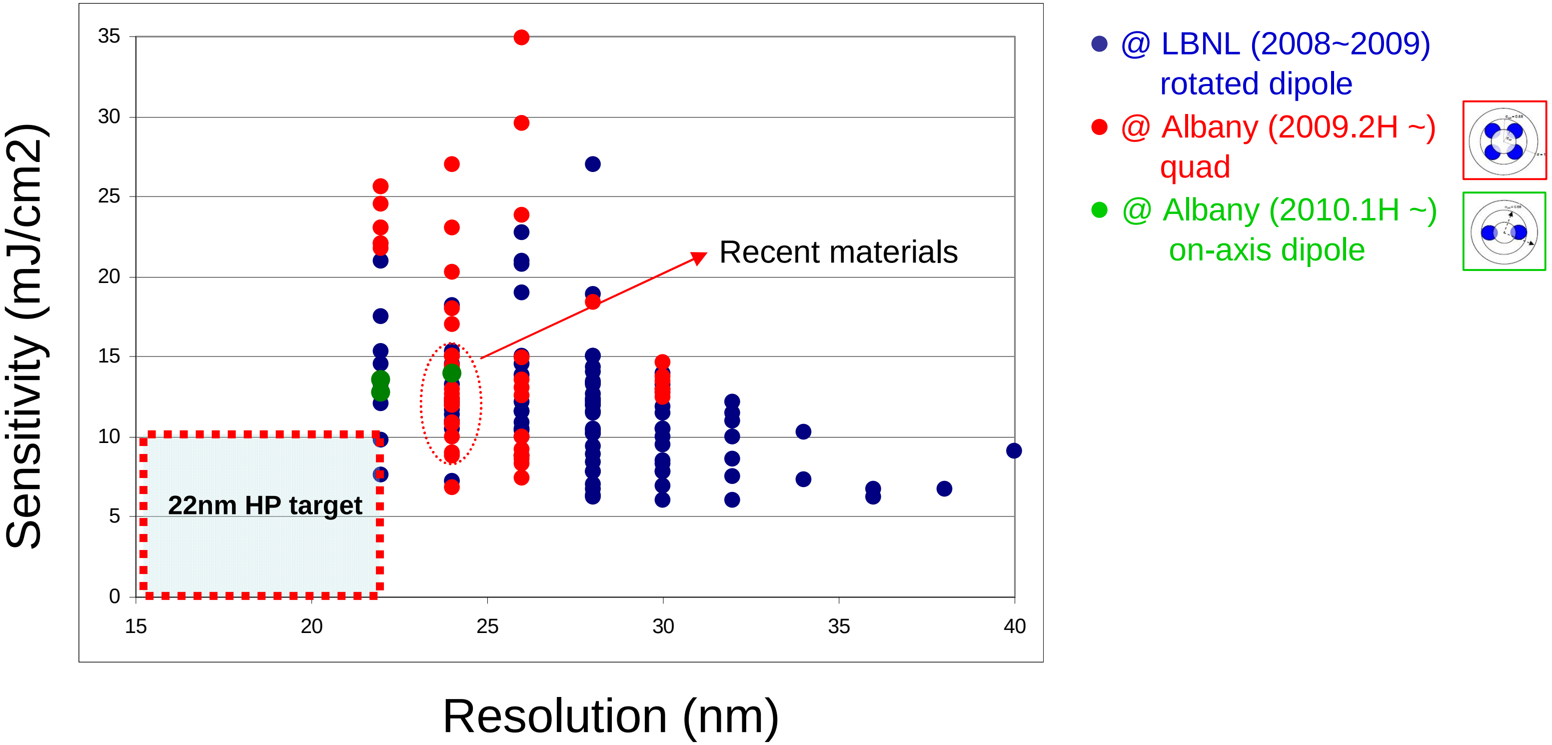
EUV Resist Performance Status



- Resolution moves downward and almost meets the 22 nm HP.
- For LER, there is a barrier around 4 nm that we need to break through.

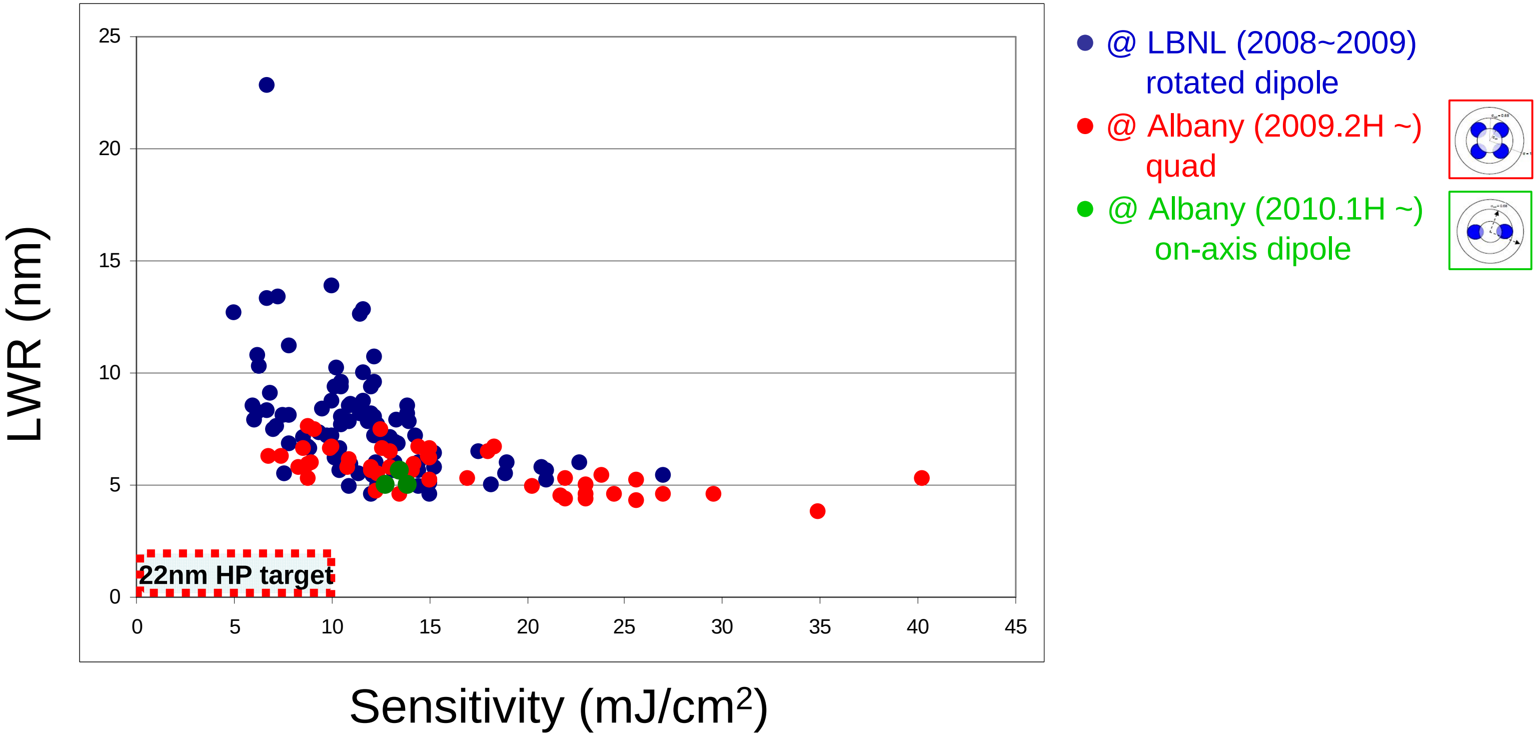
- Using dipole, we can get a smaller pattern with same resist.

EUV Resist Performance Status



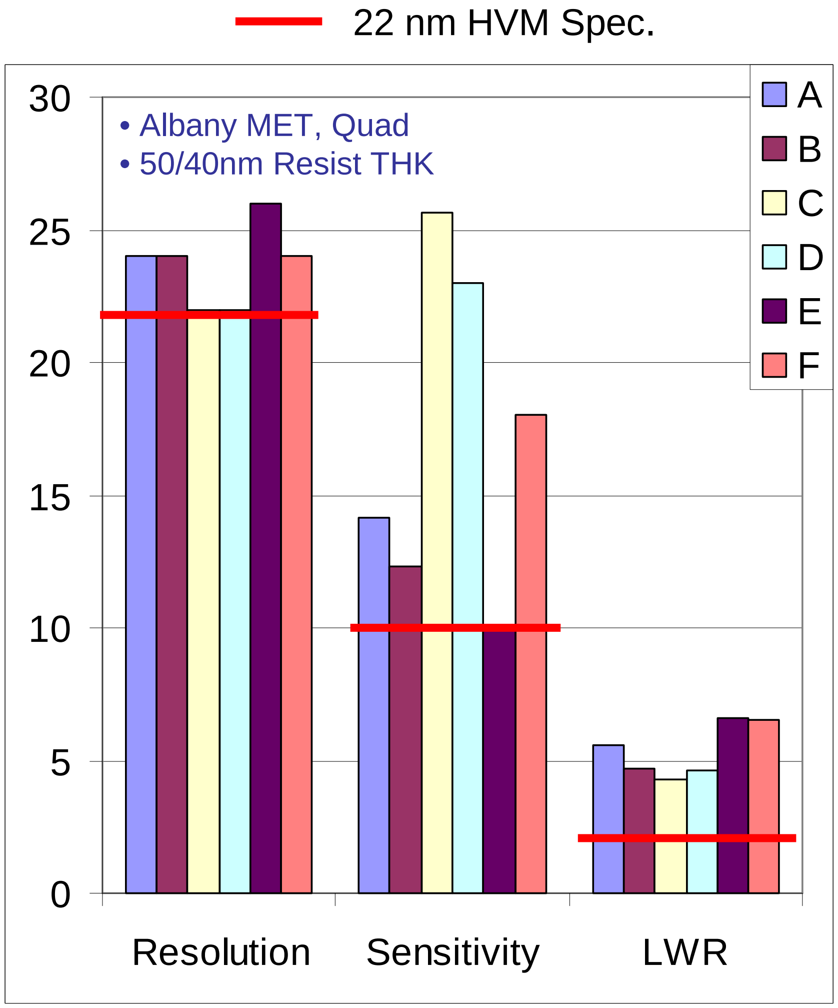
- There is no improvement in sensitivity, but it is already close to the target.

EUV Resist Performance Status



- This graph shows the same results as the previous one.

Key Gap for 22 nm Patterning



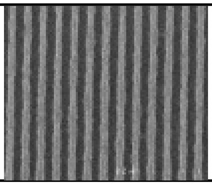
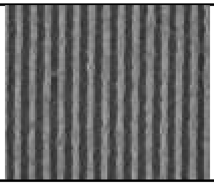
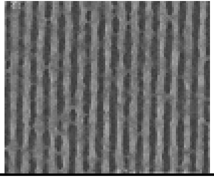
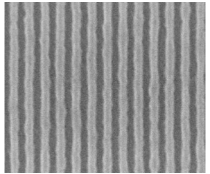
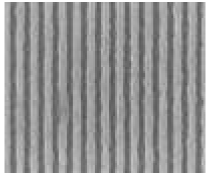
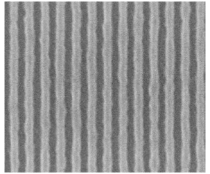
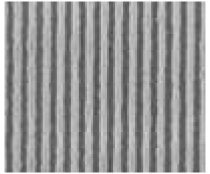
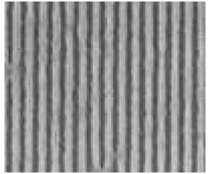
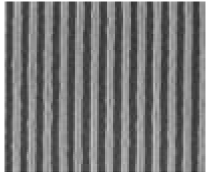
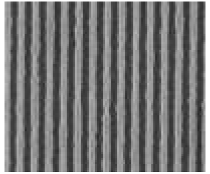
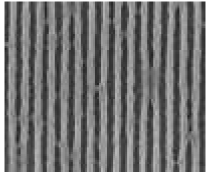
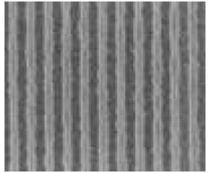
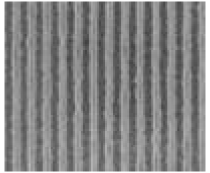
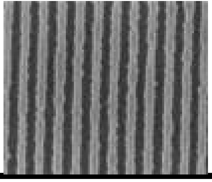
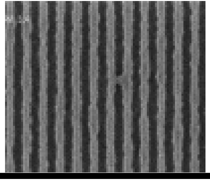
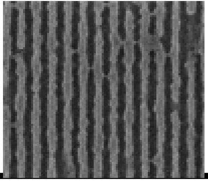
Goal **22 nm HP 10mJ/cm² 1.4 nm**

- Key Gaps for 22 nm HP Patterning

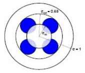
1. LWR
2. Collapse
3. Sensitivity
4. Resolution

5. Defect (bridge/scum)
6. Pattern transfer with thin resist

Sub 26 nm Patterning Fidelity of EUV Resists

	26 nm	24 nm	22 nm	20 nm
A				
B				
C				
D				
E				
F				

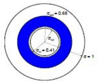
These images are taken from the best material of each supplier.

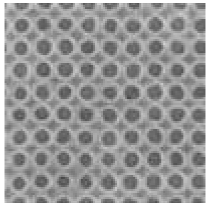
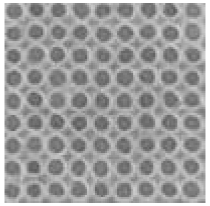
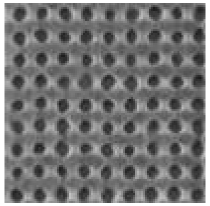
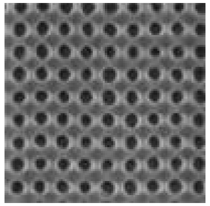
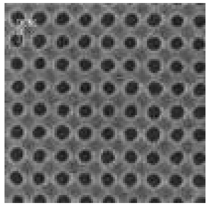
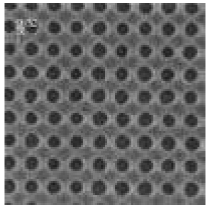
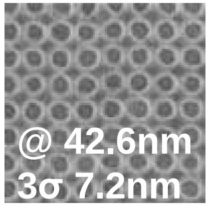
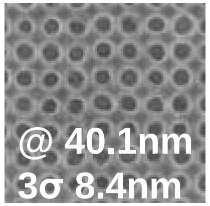
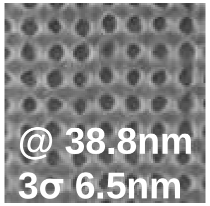
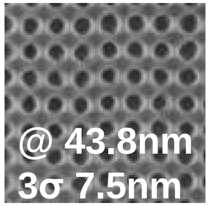
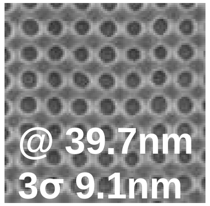
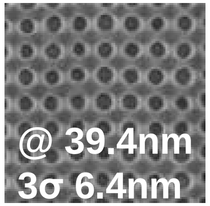
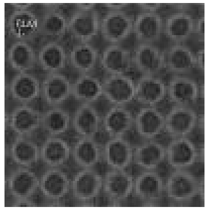
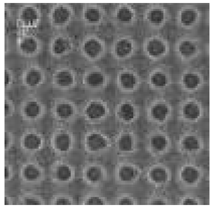
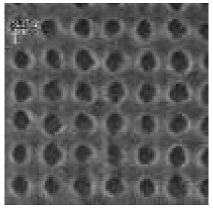
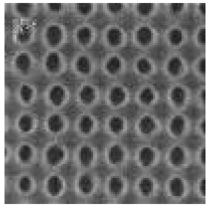
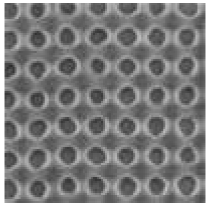
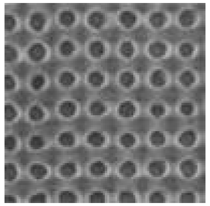


- Albany MET, Quad
- 50/40 nm Resist THK

Patterning Fidelity of EUV Resists
- Contact Hole Pattern

- Albany MET, Annular
- 80nm Resist THK



Supplier	A1	A2	B1	B2	C1	C2
Energy	32mJ/cm^2	31mJ/cm^2	41mJ/cm^2	35mJ/cm^2	39mJ/cm^2	40mJ/cm^2
30nm						
35nm	 @ 42.6nm 3σ 7.2nm	 @ 40.1nm 3σ 8.4nm	 @ 38.8nm 3σ 6.5nm	 @ 43.8nm 3σ 7.5nm	 @ 39.7nm 3σ 9.1nm	 @ 39.4nm 3σ 6.4nm
40nm						

- Energy to size is too high & size variation is a problem.

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- Rinse material – LWR & collapse improvement
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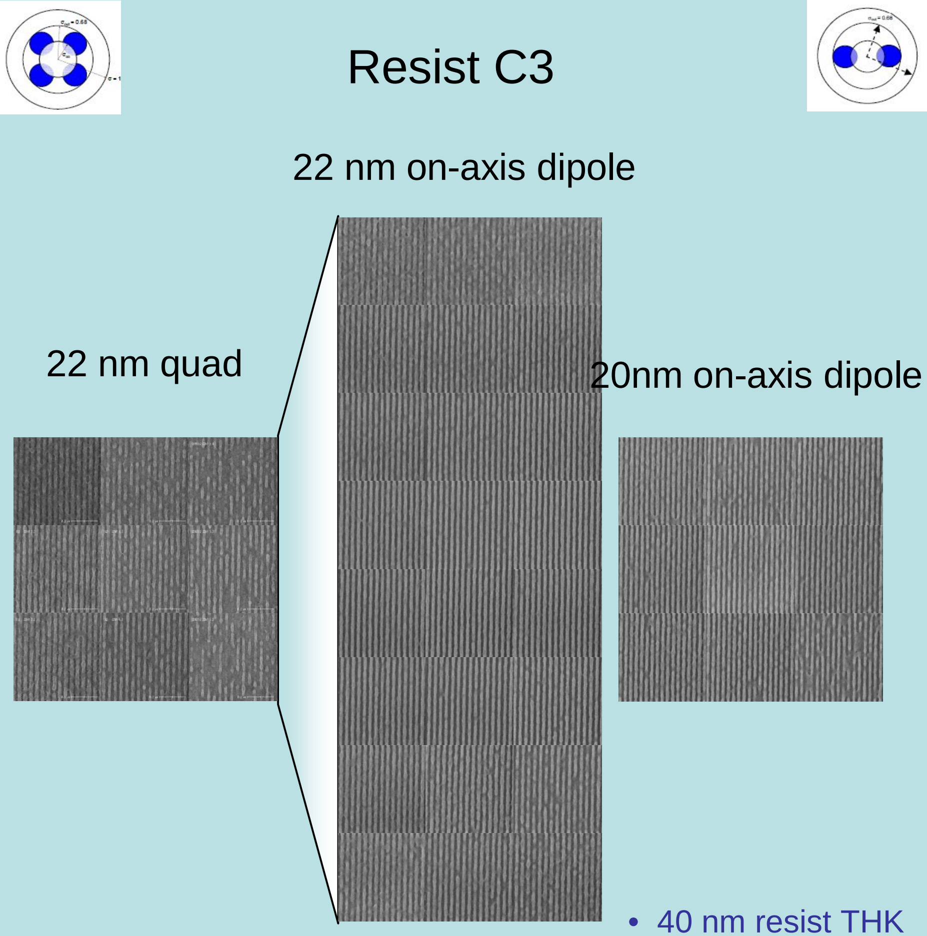
Patterning Fidelity of EUV Resists – On-axis Dipole



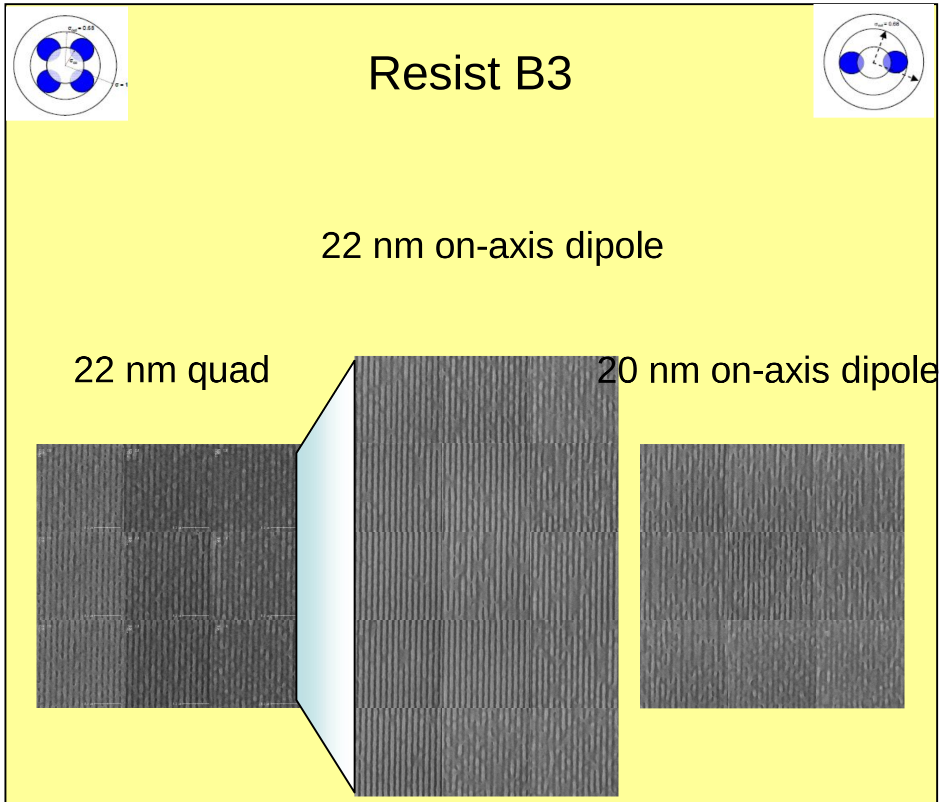
Resist C3

22 nm on-axis dipole

22 nm quad

20nm on-axis dipole

- 40 nm resist THK



Resist B3

22 nm on-axis dipole

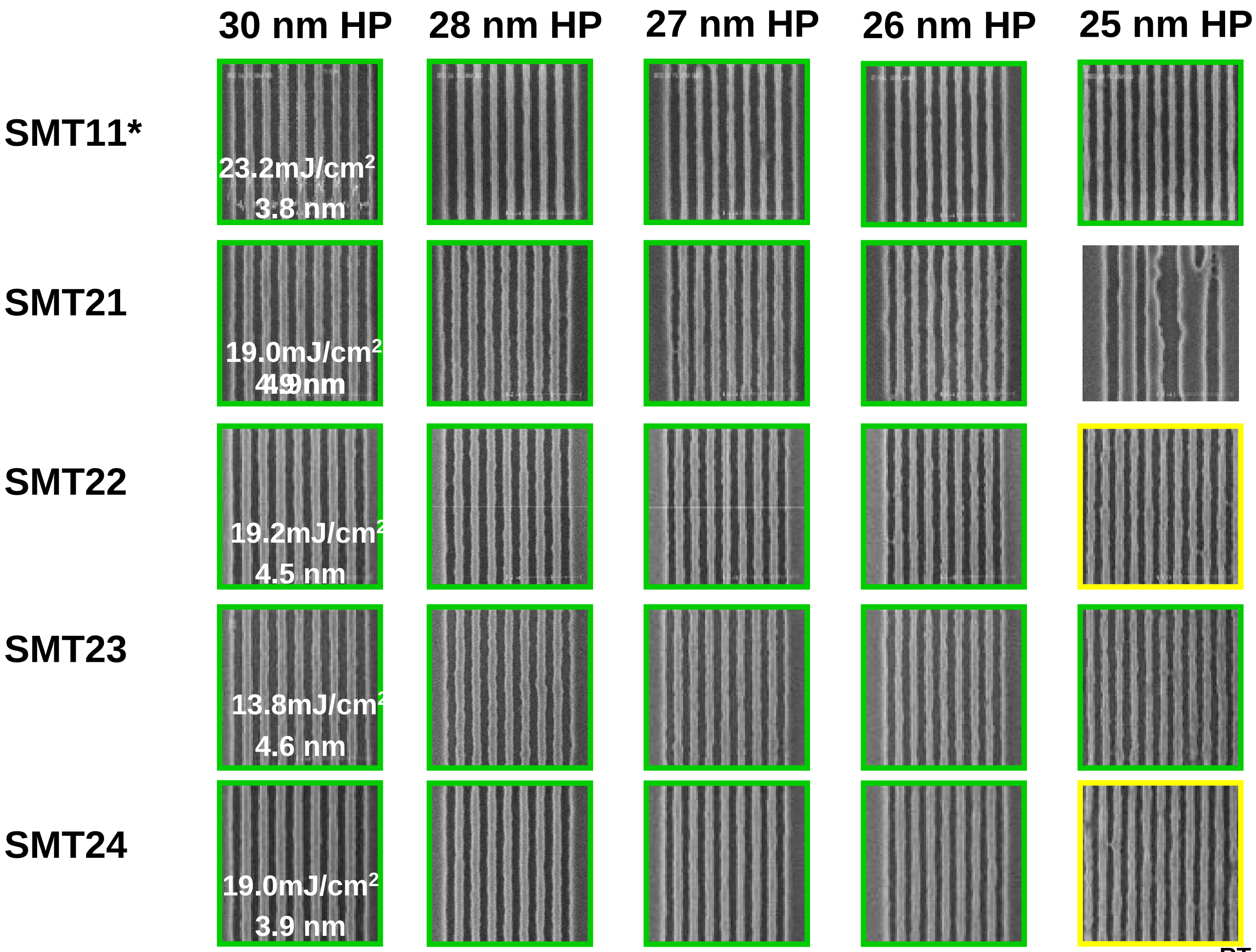
22 nm quad

20 nm on-axis dipole

- 40 nm resist THK

In general, on-axis dipole imaging capability has increased.

Patterning Results of EUV resist on ADT

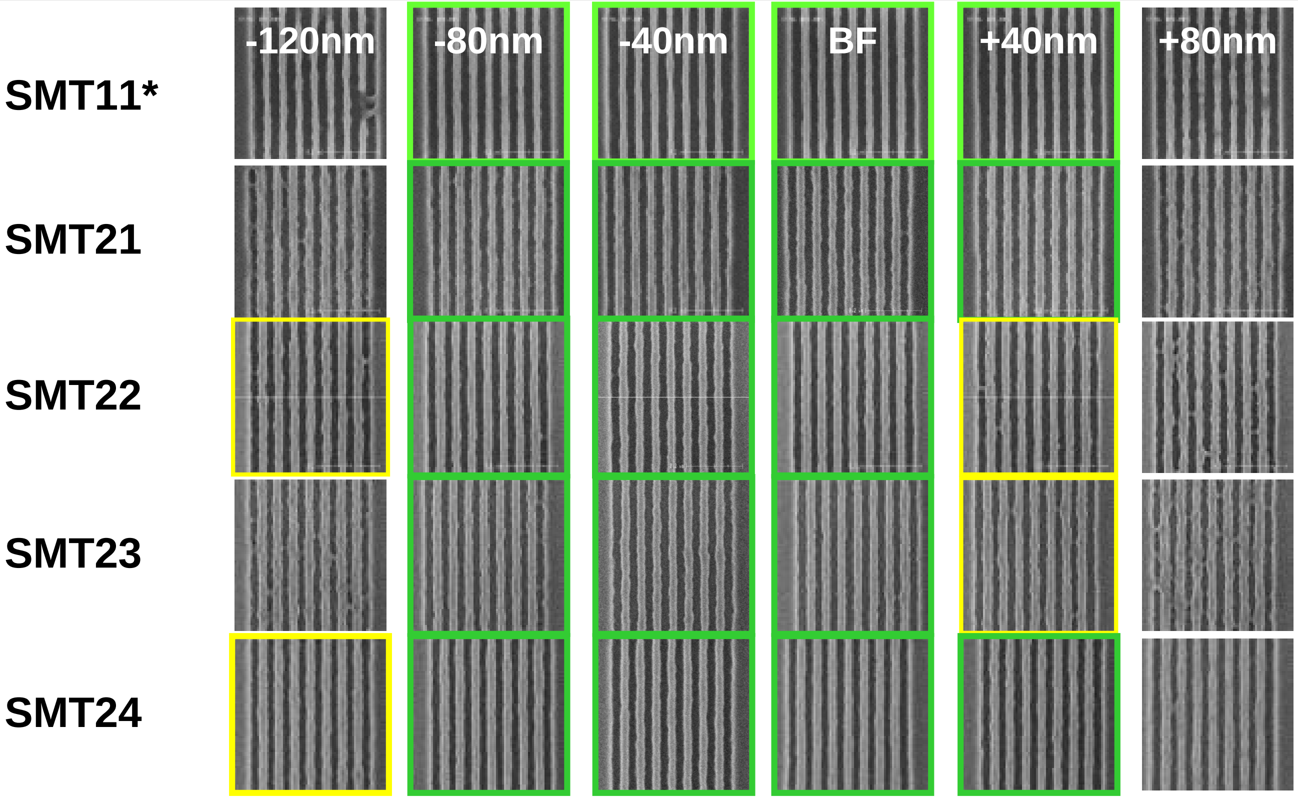


Best material

RT : 50 nm on underlayer
*** : 60 nm on underlayer**
On ADT

Resist Imaging Performance at 28 nm HP

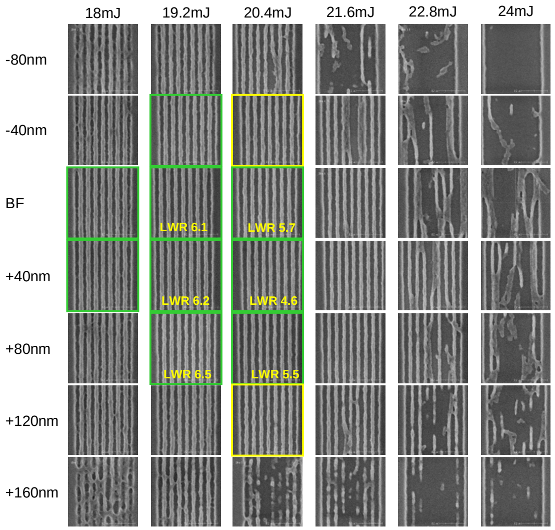
Resist	28nm HP L/S				Min. Resolution (HP)	Comment
	Esize (mJ/cm^2)	LWR (nm)	% EL	DOF(nm)		
SMT11*	23.2	5.2	%	120	25	Polymer Bound PAG
SMT21	19.0	5.8	18	120	26	PHS Hybrid
SMT22	19.2	5.5	13	80	~25	PHS Hybrid
SMT23	13.8	6.0	17	80	25	Polymer Bound PAG
SMT24	19.0	5.3	13	120	~25	Acrylate polymer



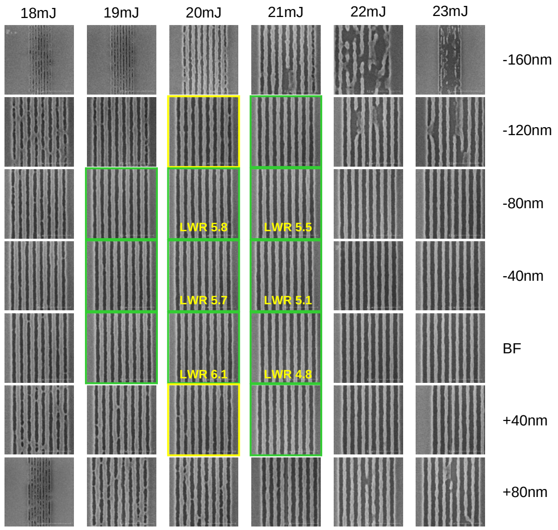
Best material
- reference

RT : 50nm on underlayer
*** : 60nm on underlayer**
On ADT

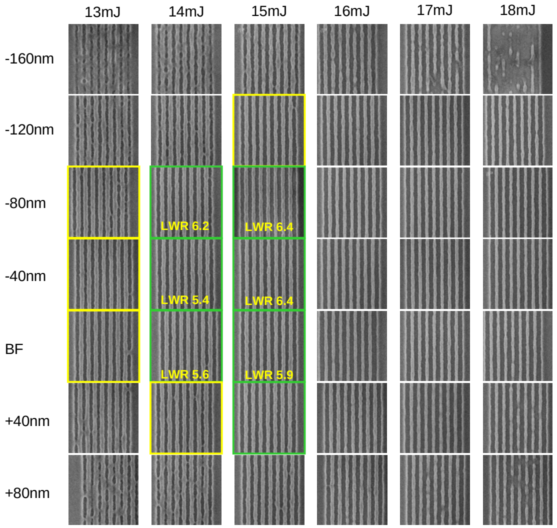
Process Window @ 28 nm HP



SMT21



SMT22



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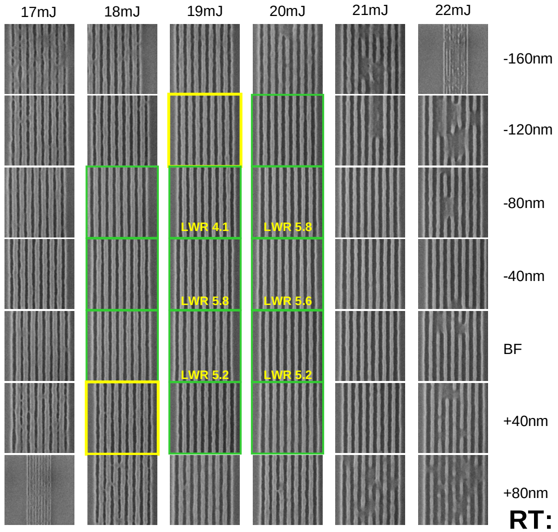
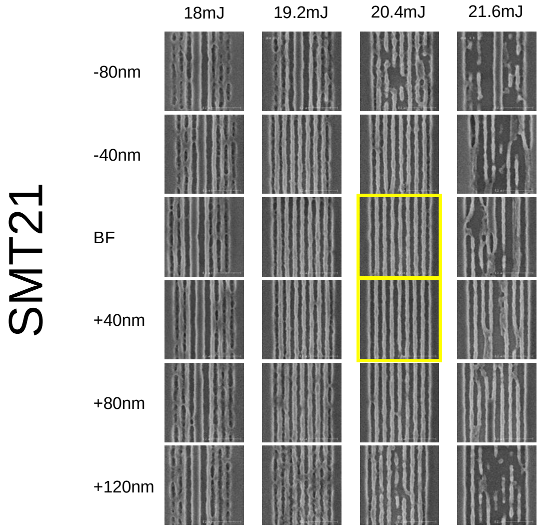


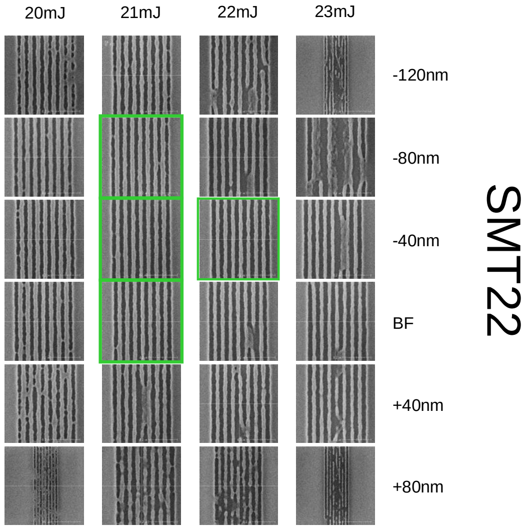
SMT24

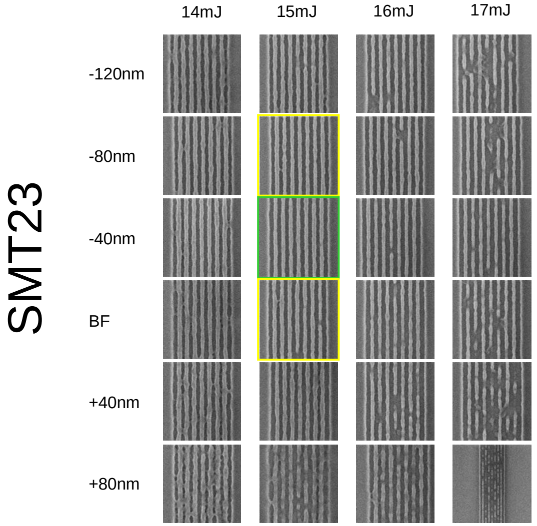
RT: 50 nm on underlayer
On ADT

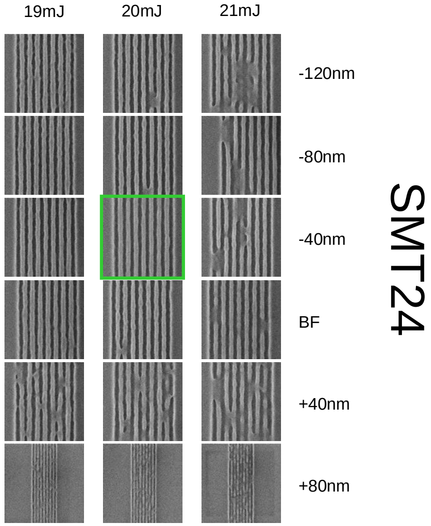
Process Window @ 26 nm HP/25 nm HP

26 nm HP

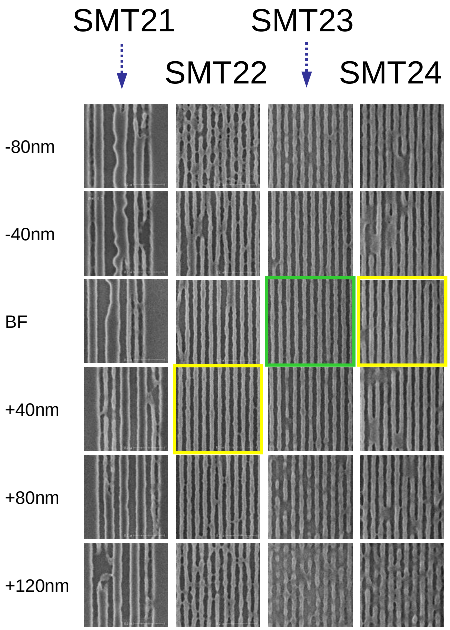






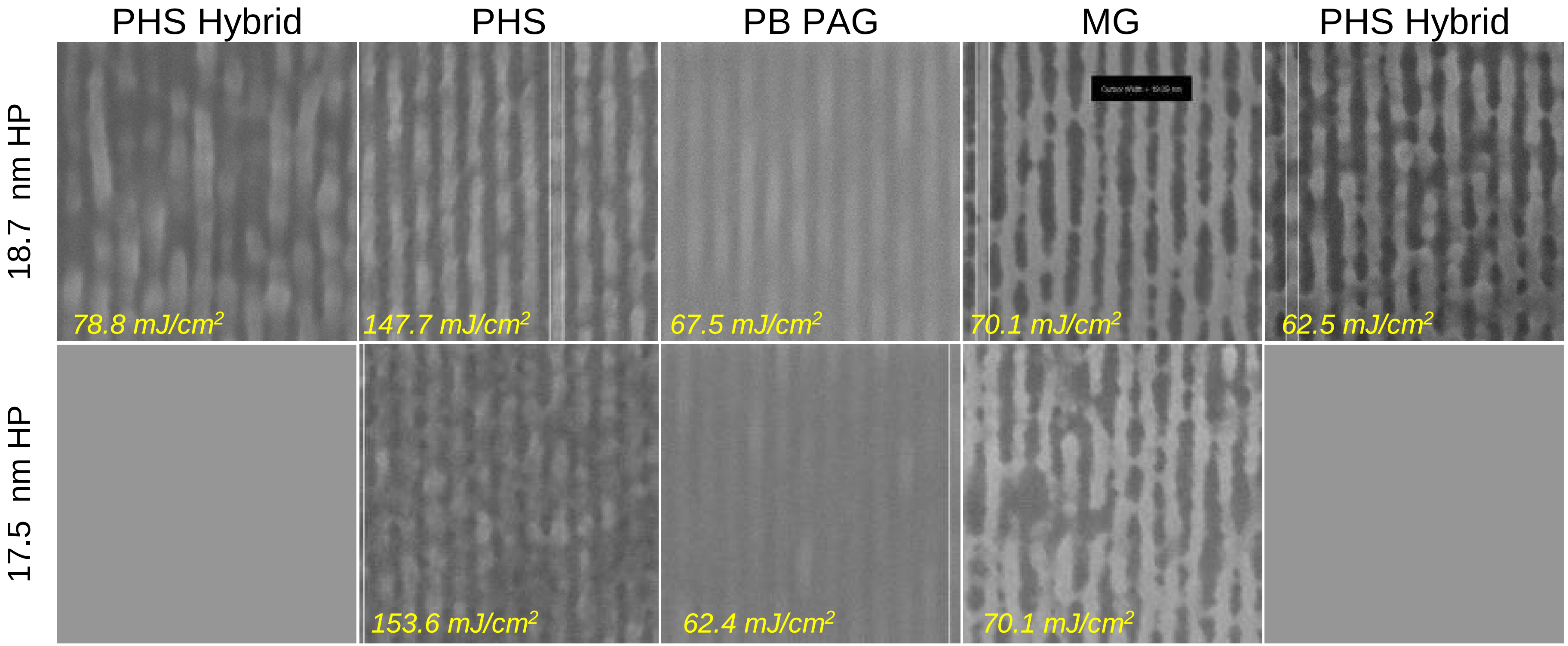


25 nm HP



RT: 50 nm on underlayer
On ADT

Evaluation Results @ PSI



- We selected some candidates for the resolution limit @ PSI
- Extendibility of CAR in each platform

- 3 resists have modulation @ 17.5 nm

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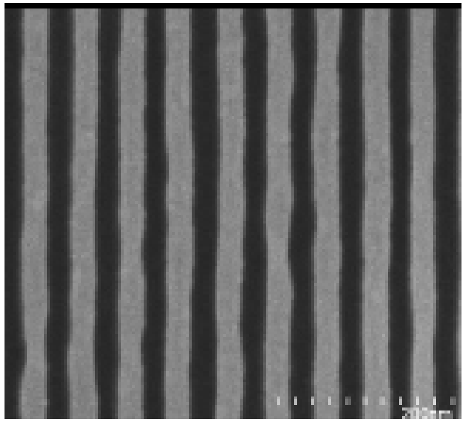
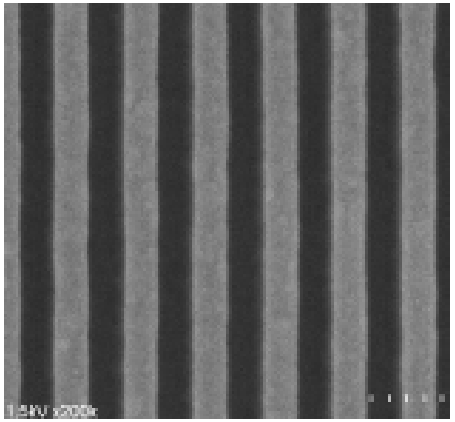
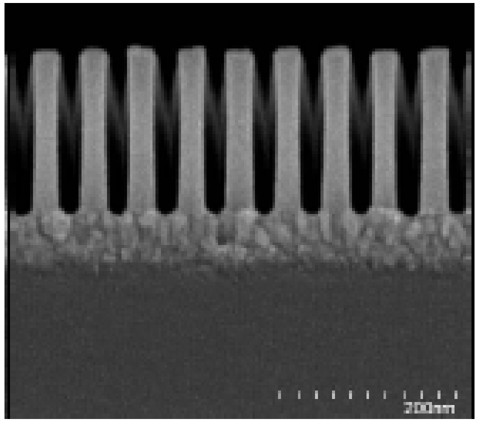
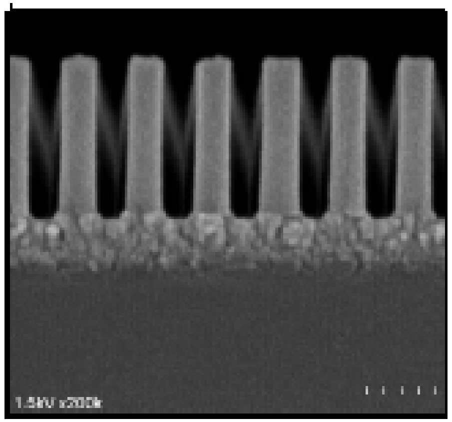
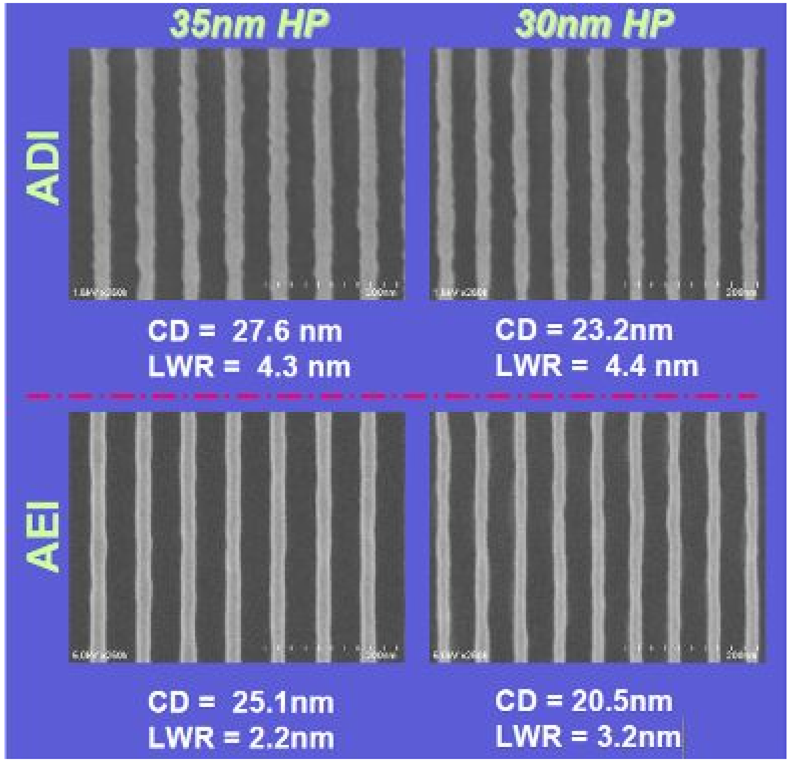
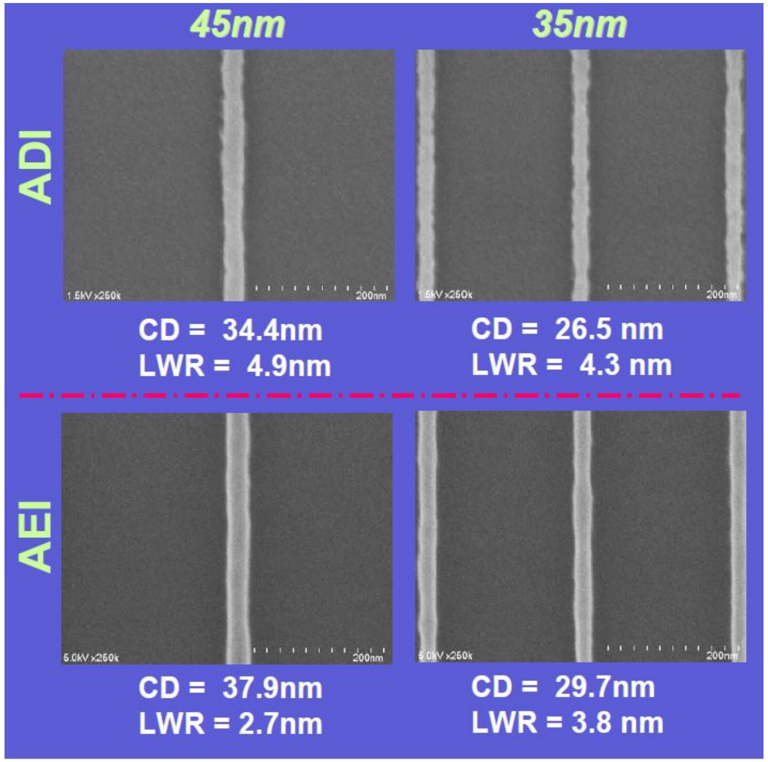
Pattern Transfer Results

- Successfully demonstrated pattern transfer of 28 nm HP L/S

	28 nm HP	40 nm HP
Top View		
Vertical View		

LWR Reduced by Dry Etch



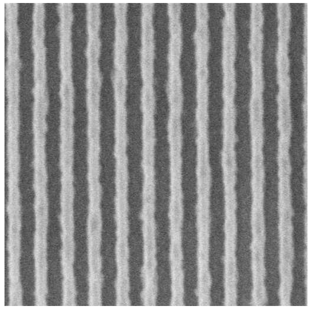
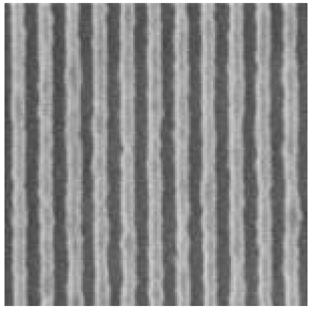
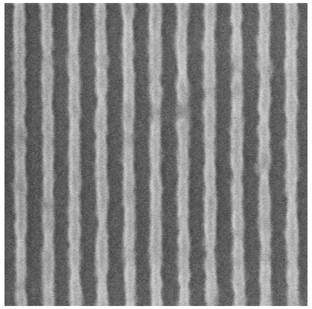
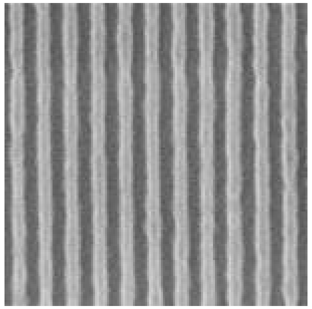


- Current best 2.2 nm LWR on 35 nm HP
- ~50% reduction of LWR by dry etch

This page is addressed more detail in George Huang’s poster

LWR Improvement with a Rinse Material

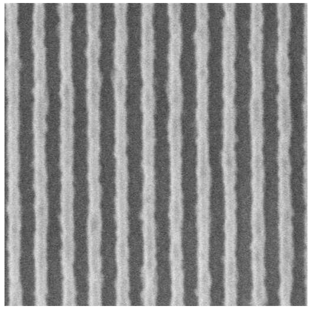
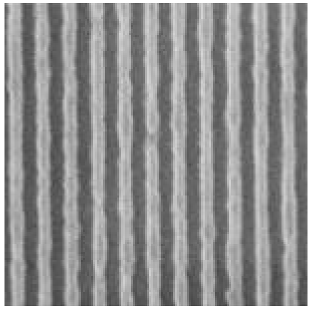
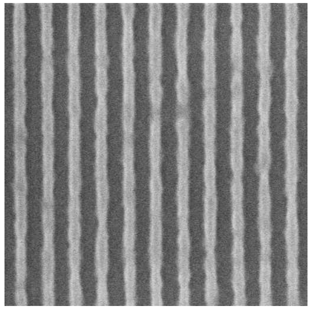
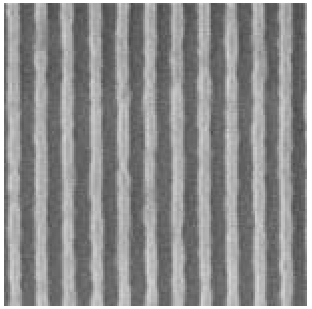
- SEMATECH Albany MET, quadrupole illumination
- 60 nm resist thickness on underlayer

Resist	B4(PHS hybrid)		C4 (PB PAG, 193 nm platform)	
30 nm HP	DIW rinse	Rinse B1	DIW rinse	Rinse B1
				
LWR (nm)	5.6	5.7	6.1	5.2
LWR Improvement	-	-0.1 nm (-1.8%)	-	0.9 nm (15%)
ADI CD	24.7 nm @ 13.5mJ/cm^2	28.5 nm (+3.8 nm) 13.5mJ/cm^2	23.7 nm @ 10.0mJ/cm^2	27.6 nm (+3.9 nm) @ 10.0mJ/cm^2

- Resist LWR improves with rinse material, but was largely dependent on the resist platform.
- 0.9 nm LWR (15%) improvement was demonstrated at 30 nm HP of C3 using rinse material B1. CD changes need to be minimized.

LWR Improvement with a Rinse Material

- SEMATECH Albany MET, Quadrupole illumination
- 60 nm resist thickness on underlayer

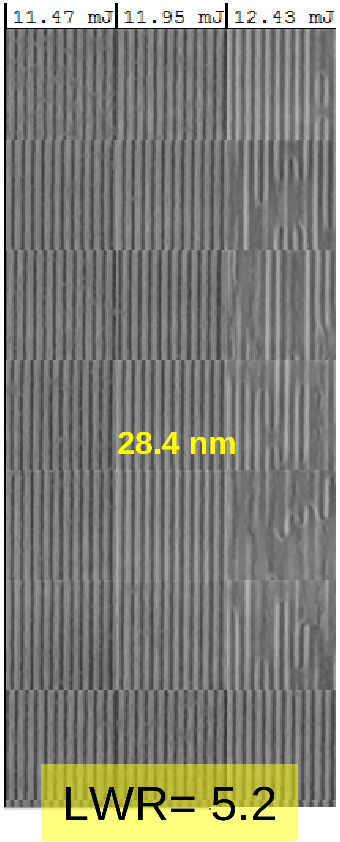
Resist	B4(PHS hybrid)		C4 (PB PAG, 193 nm platform)	
30 nm HP	DIW rinse	Rinse B2	DIW rinse	Rinse B2
				
LWR (nm)	5.6 →	5.8	6.1 →	5.5
LWR Improvement	-	-0.2 nm (-3.5%)	-	0.6 nm (9.8%)
ADI CD @ 13mJ/cm^2	24.7 nm @ 13.5mJ/cm^2	27.1 nm(+2.1 nm) 13.5mJ/cm^2	23.7 nm @ 10.0mJ/cm^2	23.5 nm (-0.2 nm) @ 10.0mJ/cm^2

- CD change also was largely dependent on the resist platform.
- 0.6 nm LWR (9.8%) improvement was demonstrated at 30 nm HP of C3 with using Rinse material B2 without a CD change.

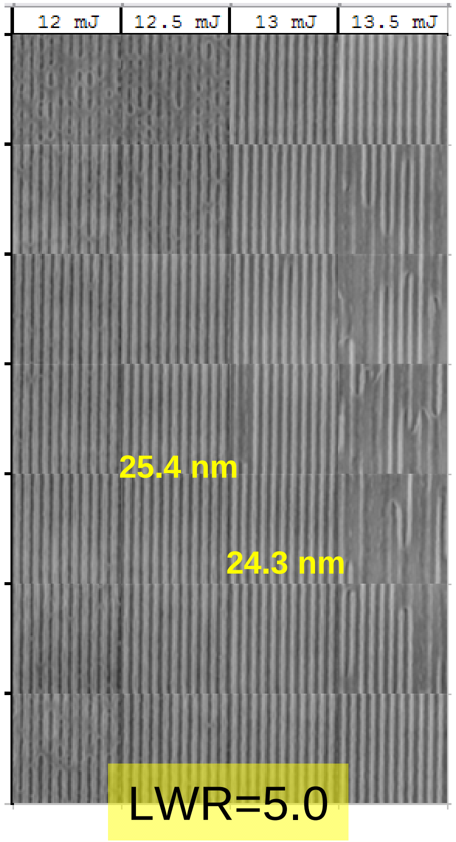
Resist C4, 30 nm HP, 75 nm Film Thickness

50 nm focus steps

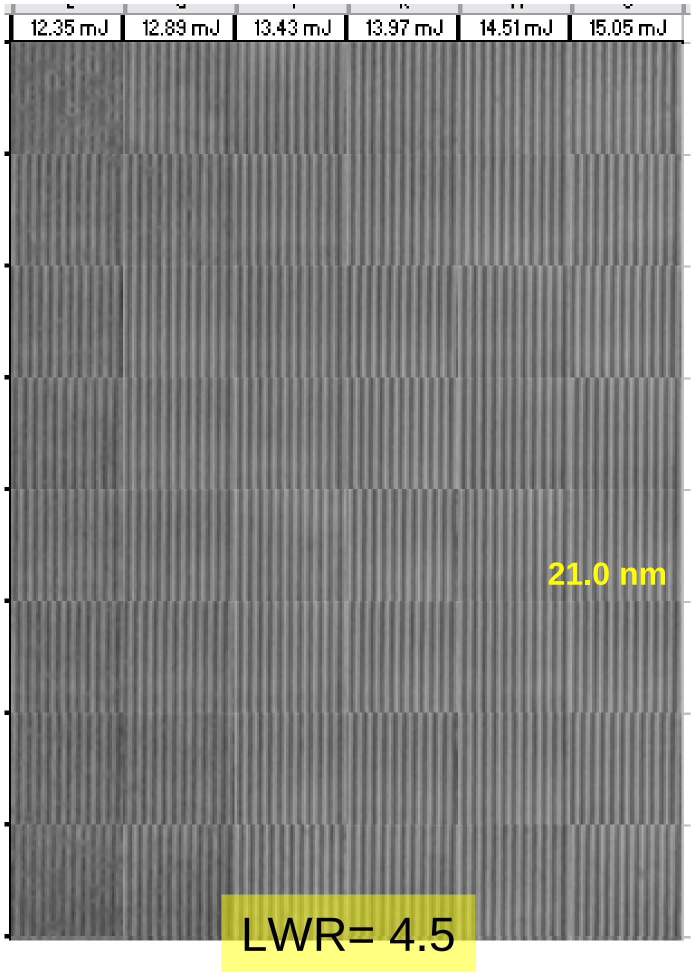
TMAH



TBAH



TBAH with Rinse C



Combination of TBAH and rinse C improve LWR and collapse.

This page is addressed in more detail in Karen Petrillo’s poster

Summary

- The Albany eMET serves as SEMATECH's baseline tool for volume testing of resist materials at excellent resolution.
- The Berkeley MET serves as the ultimate high resolution tool for the best resists coming of the eMET

- Some samples have 22 nm resolution @ Albany MET
- Sensitivity is close to the target
- Dipole give us small features with large process window

- LWR and collapse need more improvement
- Etch process can reduce the LWR about 50%
- Rinse and rinse + TBAH can improve pattern collapse and LWR

- For contact holes, faster materials are needed

- Using the ADT, several material show imaging capability less than 26 nm

Thank you for your attention!

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