EUV resist materials at SEMATECH

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1. Objectives

Evaluate EUV resist samples focusing on resolution, photospeed, and LWR.

EUV Resist Specifications	28nm HP	23nm HP	18nmHP
Resolution (line and space 1:1, nm)			
DRAM HP	28	23	18
MPU gate	25	20	16
LWR (nm, 3σ)			
10% of DRAM HP	2.8	2.3	1.8
8% of MPU Gate	2.0	1.6	1.3
Photospeed (mJ/cm²)	10	10	10

Assumptions: Photospeed target is for 1:1 lines and spaces.

2. Tools and Evaluation Procedure

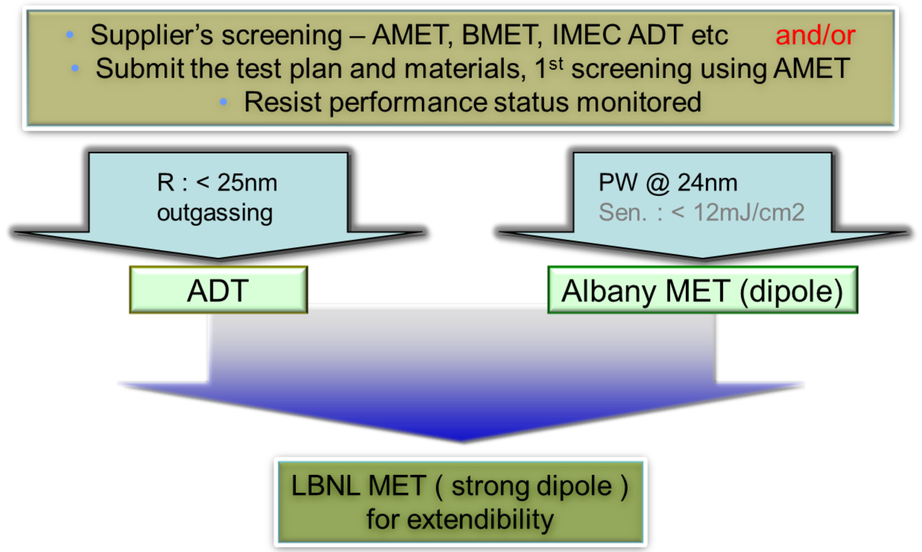
- SEMATECH ADT
  - Conventional, 0.25 NA, sigma 0.5
- SEMATECH Albany MET
  - Quadrupole, NA 0.3, sigma 0.35/0.68 for line and space
  - Dipole, NA 0.3, sigma 0.35/0.68 for line and space
  - Annular, NA 0.3, sigma 0.4/0.68 for contact hole
- SEMATECH Berkeley MET
  - "18 nm dipole"
  - Pseudo PSM, near future

- Procedure

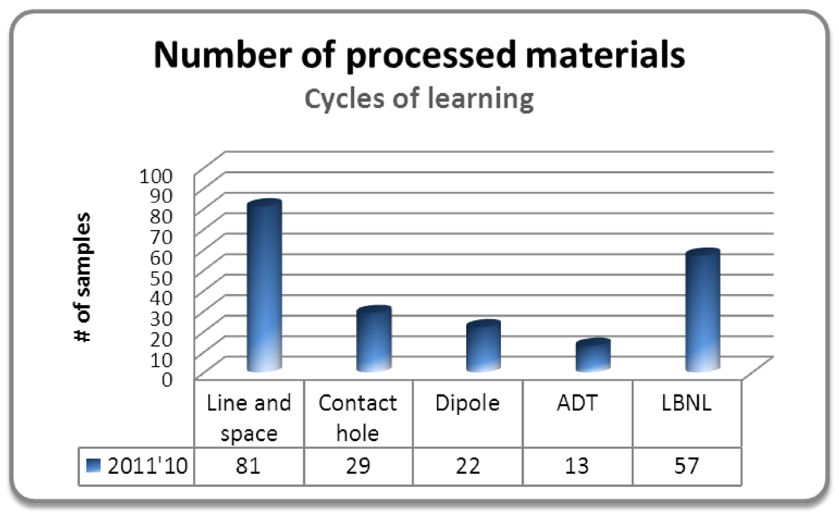
Using quadrupole illumination @ Albany MET as baseline tool,

Materials showed good performance; those samples were exposed using dipole illumination @ AMET and ADT for further evaluation.

We use the Berkeley MET for finding a path to sub-20 nm patterning.

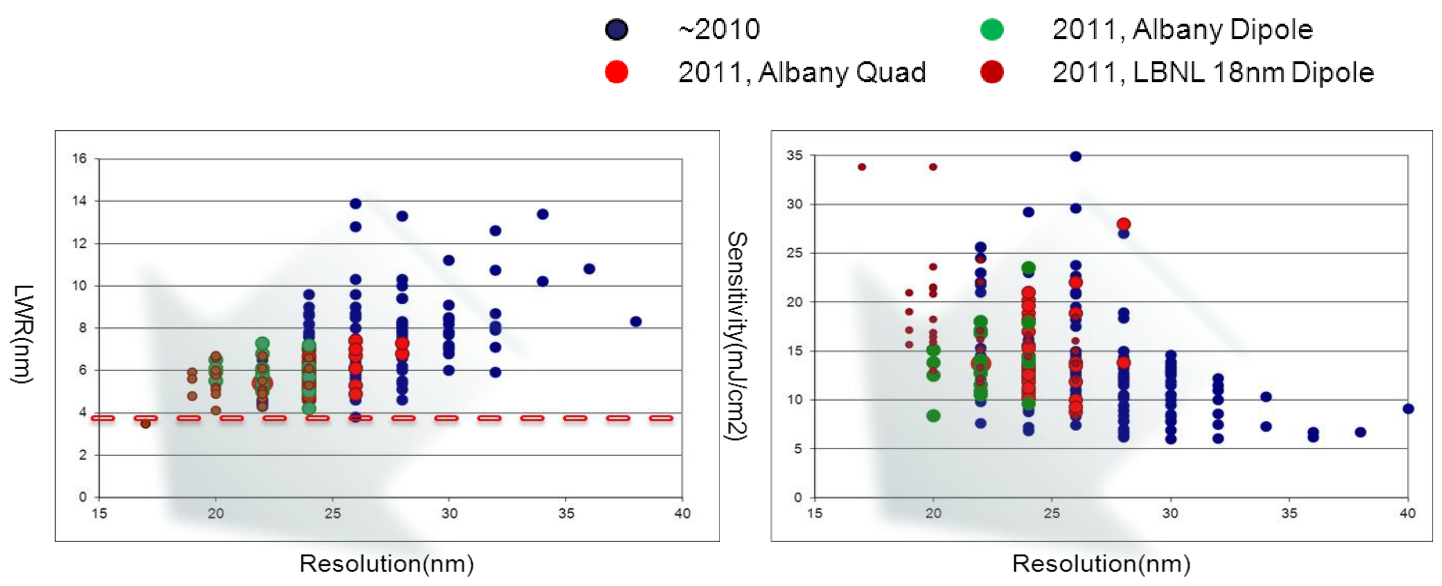


3. Number of Processed Materials (COL)



- More than 200 wafers were exposed in this year.

4. Current Performance Status

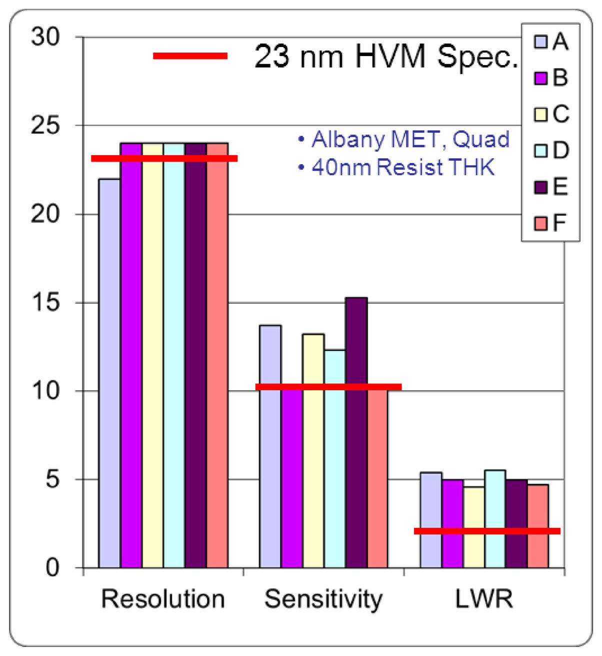


- Resolution has moved downward, and sub-20 nm resolution has been demonstrated by using optimized illumination conditions.
- Sensitivity has improved to close to target.
- LWR, remains around 5 nm, has not improved.

4 a. Cycles of Learning – @ Albany MET

Quadrupole illumination

Goal 23 nm HP 10mJ/cm² 1.6 nm



Patterning Fidelity of EUV Resists with Quad @ AMET
- Best resist for each suppliers

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

@40nm thickness

- A number of suppliers are making progress with sensitivity and resolution.
- LWR has not improved.

Dipole illumination

	24nm	22nm	20nm	19nm	18nm	17nm
A 15.12mJ/cm2 LWR : 5.1nm						
B1 18.0mJ/cm2 LWR : 5.4nm						
C1 13.8mJ/cm2 LWR : 5.5nm						
D1 12.45mJ/cm2 LWR : 5.5nm						
E1 18.0mJ/cm2 LWR : 5.7nm						
F1 14.1mJ/cm2 LWR : 5.5nm						

@40nm thickness

- Using dipole illumination, we can get 20 nm resolution and 19 nm image modulation.

Contact hole with Annular illumination

Resist	A2	B2	C2	D
Local CDU @30nm HP	4.41nm	7.06nm	6.45nm	4.98nm
30nm HP	34.3nm @ 43.0mJ	36.7nm @ 33.6mJ	38.9nm @ 41.6mJ	37.7nm @ 46.7mJ
35nm HP	41.1nm @ 36.98mJ	43.8nm @ 28.9mJ	41.1nm @ 32.87mJ	43.2nm @ 43.17mJ

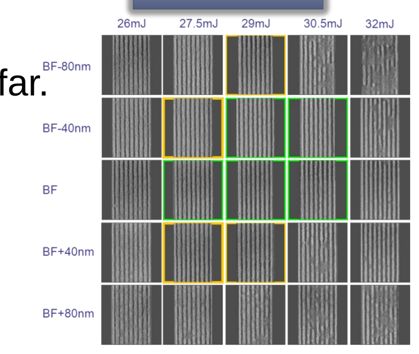
- Resists for contact hole patterning should be faster and have low CDU.

4 b. Cycles of Learning – @ Albany ADT

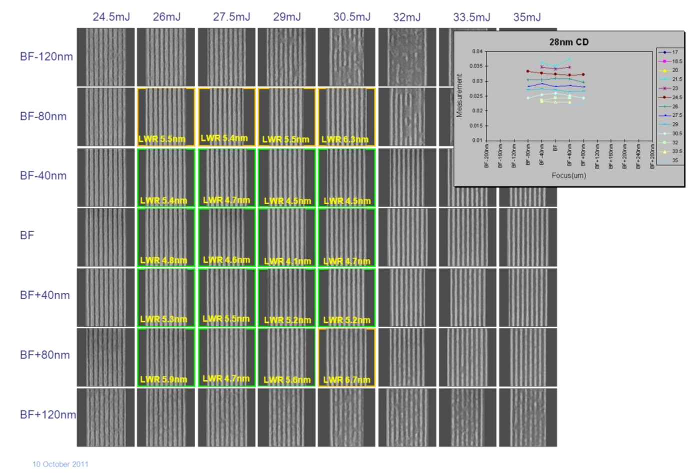
Resist	28nm HP L/s Esize (mJ/cm²)	LWR (nm)	% EL	DOF (nm)	Min. Resolution (nm HP)	28nm HP	26nm HP	25nm HP
B3	28.3	4.9	17.9	>120	25			
C3	16.2	6.5	14.6	120	26			
D1	24.1	5.9	15.1	120	~25			
D3	16.0	6.4	13.9	120	~25			
E2	14.4	6.8	14.4	120	~26			

- 25 nm resolution was demonstrated on the ADT.
- **B3** shows the best performance among the materials exposed on the Albany ADT so far. It has a wide process window @ 28nm HP and resolving capability @ 25nm HP.

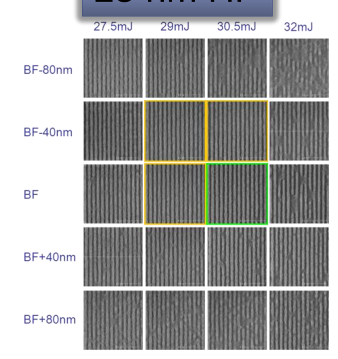
26 nm HP



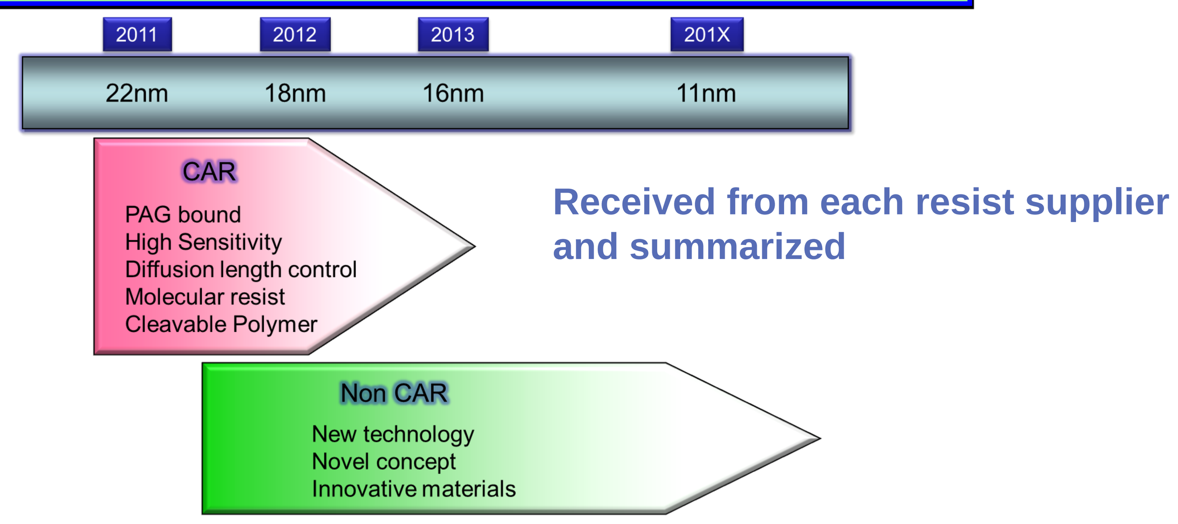
28 nm HP



25 nm HP



4 c. Strategy for Sub-20 nm



Received from each resist supplier and summarized

	24nm	22nm	20nm	19nm	18nm	17nm
A 19.0mJ LWR 5.3nm						
B4 11.77mJ/cm2 5.1nm						
C4 16.83mJ/cm2 5.1nm						
D4 33.8mJ LWR 3.5nm						
E3 12.95mJ/cm2 6.7nm						
F2 12.2mJ/cm2 5.5nm						

- For sub-20 nm imaging capability, we use 18 nm-dipole @ the Berkeley MET.
- A CAR-type resist showed 17 nm resolution.

6. Summary

- A number of suppliers are making progress in improving the sensitivity of materials.
- Resolution has not improved using quadrupole illumination @ the AMET; however, dipole illumination @ the AMET has demonstrated 20 nm HP resolution with several materials.
- LWR still requires a great deal of effort.
- Contact hole materials have shown little apparent improvement; however, the sample set is limited and more materials will need to be evaluated.
- Many materials showed sub-26 nm resolution @ the Albany ADT.
- Some material showed promising results for 18 nm HP and smaller patterning.