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Benchmarking commercial EUVL resists at SEMATECH

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Benchmarking Commercial EUVL Resists at SEMATECH

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SEMATECH

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Accelerating the next technology revolution.

Outline

- Introduction
- Objective
- Methodology
- Benchmarking Data
- Summary

Introduction

- Extreme ultraviolet lithography (EUVL) is one of the leading candidates for next generation lithography technology for the 32 nm HP and beyond.
- The availability of EUV resists is one of the most significant challenges facing its commercialization.
- To accelerate EUV resist development, SEMATECH provides access to two exposure tools:
 - The EUV Resist Test Center (RTC) at SEMATECH at the University at Albany, SUNY, NY.
 - The SEMATECH microexposure tool (ALS-MET) at Lawrence Berkeley National Laboratory (LBNL).
- The results presented here were collected on the SEMATECH Berkeley MET with the same illumination and resist thickness.

Objective

- Evaluate resist samples from commercial suppliers with well defined protocols and specification targets.
 - Provide suppliers with a benchmarking data package using a consistent protocol for feedback and improvement.
 - Focus on resolution, LWR, and photospeed.

Specifications	2007 Goals
Resolution lines 1:1 (nm)	32
Resolution lines 1:5 (nm)	25
Resolution contact holes 1:1 (nm)	45
Resolution contact holes 1:5 (nm)	45
Low frequency LWR (nm, 3 σ)	<2.5
Photospeed, EUV (mJ/cm ²)	10
Outgassing (molecules/cm ²)	6.5E+14

Assumptions: Resolution results confirmed with cross-sectional SEM. Resolution targets can be met with Y-monopole illumination. Photospeed target is for 1:1 lines. Outgassing spec is for 35-200 AMU excluding 44 AMU.

Resist Benchmarking Protocol Procedure

SEM Top View

Berkeley MET
Rotated dipole

Exposure Latitude (EL) @ 40 nm HP

Resist A
Best Focus

Resist B
Best Focus

Resist C
Best Focus

Resist D
Best Focus

Resist E
Best Focus

Dose

CD/LWR

- Resist A and C demonstrated 15% of EL at 40 nm HP

Berkeley MET

Rotated dipole

Depth of Focus (DOF) at 40 nm HP

	BF-100 nm	BF-50 nm	Best Focus	BF+50nm	BF+100 nm	BF+150 nm
Resist A 20.7 mJ/cm ²	44.8/ 10.3	42.3/ 7.9	41.4/ 9.3	39.0/ 6.8	40.2/ 9.5	39.8/ 8.5
Resist B 16.15 mJ/cm ²	39.6/ 11.2	40.1/ 9.2	39.5/ 7.3	39.7/ 8.5	39.8/ 9.6	42.8/ 7.7
Resist C 20.0 mJ/cm ²	37.8/ 12.8	38.4/ 10.7	40.0/ 8.6	40.8/ 7.3	39.1/ 9.1	41.8/ 9.5
Resist D 24.3 mJ/cm ²	43.8/ 7.8	41.5/ 8.0	42.6/ 9.7	40.9/	43.1/ 20.9	33.1/ 6.7
Resist E 18.1 mJ/cm ²	38.7/ 11.2	41.8/ 9.1	40.8/ 7.3	41.4/ 7.3	39.3/	44.0/ 13.4

CD/LWR

- Resist A demonstrated 200 nm of DOF on 40 nm HP

Berkeley MET

Rotated dipole

Summary of Dose/Focus Process Latitude at 40 nm HP

Resist Name	Resist THK (nm)	Illumination	Mask	Esize (mJ/cm ²)	Exposure Latitude(%)	DoF (nm)	Ultimate Imaging (CD/LWR)
Resist A	50	Rot-Dipole	Horizontal Cleave	20.7	20.0	200	26.5/ 8.5
Resist B	50	Rot-Dipole	Horizontal Cleave	16.15	20.0	200	24.1/ 6.2
Resist C	50	Rot-Dipole	Horizontal Cleave	20.0	20.0	200	29.8/ 8.4
Resist D	50	Rot-Dipole	Horizontal Cleave	19.0	20.0	200	26.3/ 6.2
Resist E	50	Rot-Dipole	Horizontal Cleave	18.1	15.0	150	34.1/ 7.1

- Resist B demonstrated 20% of EL and 200nm of DOF @ 40nm HP with Esize 16.15 mJ/cm².

Exposure Latitude (EL) at 30 nm HP

Resist A
Best Focus

Resist B
Best Focus

Resist C
Best focus

Resist D
Best Focus

- Resist A demonstrated 20.0% of EL at 30 nm HP

Berkeley MET

Rotated dipole

Depth of Focus (DOF) at 30 nm HP

	BF-100 nm	BF-50 nm	Best Focus	BF+50nm	BF+100 nm	BF+150 nm
Resist A 20.7mJ/cm ²	36.3/ 9.3	32.6/ 10.1	30.2/ 6.1	31.5/ 6.8	28.8/ 10.2	32.9/ 9.0
Resist B 17 mJ/cm ²	29.8/ 6.8	30.9/ 7.5	29.3/ 5.5	28.9/ 8.0	30.2/ 8.1
Resist C 20.9 mJ/cm ²	28.8/ 11.7	28.9/ 7.9	29.2/ 7.5	29.8/ 8.5	27.6/ 6.4	29.2/ 7.8
Resist D 20.0 mJ/cm ²	30.7/ 7.7	29.4/ 5.2	32.5/ 7.6	31.3/ 10.9	31.2/ 10.8	31.8/ 14.2

- Resists A and D demonstrated 200 nm of DOF at 30 nm HP

Berkeley MET

Rotated dipole

Summary of Dose/Focus Process Latitude at 30 nm HP

Resist Name	Resist THK (nm)	Illumination	Mask	Esize (mJ/cm ²)	Exposure Latitude(%)	DoF (nm)	Ultimate Imaging (CD/LWR)
Resist A	50	Rot-Dipole	Horizontal Cleave	20.7	20	200	26.5/ 8.5
Resist B	50	Rot-Dipole	Horizontal Cleave	17.0	10	150	24.1/6.2
Resist C	50	Rot-Dipole	Horizontal Cleave	20.9	2.5	200	29.8/ 8.4
Resist D	50	Rot-Dipole	Horizontal Cleave	20.0	5	200	26.3/ 6.2

- Resist A demonstrated 20% of EL and 200nm of DOF @ 40nm HP with Esize 20.7 mJ/cm².

Top View Images of Lines/Spaces

Resist A
28 nm HP

Resist B
26 nm HP

Resist C
28 nm HP

Resist D
26 nm HP

Resist E
34 nm HP

Berkeley MET

Rotated dipole

Resist B with under-layer materials resolution image comparison @ 26nm HP

Resist B
w/ HMDS

Resist B
w/ under-layer A

Resist B
w/ under-layer B

Resist B
w/ under-layer C

LER / LWR

- No visible LWR improvement from all under-layer materials, and slightly changed on photospeed.
- Observed resist collapse on under-layer A @26nm HP.

Berkeley MET

Rotated dipole

Achieved 3.6 nm of LWR @ 26 nm resolution with PAB/PEB optimization and under-layer material

Resist B
w/ HMDS
120C/ 100C

Resist B
w/ under-layer- B
120C/ 100C

Resist B
w/ under-layer- B
110C/ 100

Resist B
w/ under-layer- B
110C/ 90C

LER / LWR

- Optimized PAB/PEB temperature with underlayer material improved LWR performance significantly (from 9.4 nm → 3.6 nm) with trade-off lower photospeed which increase Esize by 20%~ 50%

Berkeley MET

Rotated dipole

SEM Top-View Images for Contact Holes in Resist B

- Resist B 45 mJ/cm²
- Mask: LBNL mask 2007-02, contact cleave cell

50 nm HP

45 nm HP

40 nm HP

35 nm HP

30 nm HP

Berkeley MET

Annular 0.35-0.55

Contact Hole Exposure Latitude (EL) and Focus Process Latitude (DOF) at 40 nm HP

Resist B
Best Focus
EL

Dose

CD

Resist B
DOF

- Resist B demonstrated 10% of EL at 40 nm HP
- Resist B demonstrated 100 nm of DOF at 40 nm HP

CD

Berkeley MET

Annular 0.35-0.55

Benchmarking conclusion (I)

Specifications	2007 Goals	Resist A	Resist B	Resist C	Resist D	Resist E
Resolution lines1:1 (nm)	32	28	26	30	26	32
Low frequency LWR (nm, 3 σ)	<2.5	6.0 @30 nm	5.5 @30 nm	7.5 @30 nm	8.2 @30 nm	N/ A
Photospeed, EUV (mJ/cm2)	10	17.25 @30 nm	17.0 @30 nm	20.9 @30 nm	20.0 @30 nm	N/ A
Outgassing (molecules/cm ²)	6.5E+14	pass	pass	pass	pass	pass

- Best process latitude @ 30-nm HP
 - Resist A: 200 nm DOF @ 20.0% EL
- Best LWR
 - Resist B: 5.5 nm (still ~ 2.2X larger than requirement)
 - 3.6 nm achieved @ 26nm HP (optimized PAB/PEB/BARC)
- Fastest resist with reasonable process latitude @ 30-nm HP
 - Resist B: 17mJ/cm2
- Best resolution
 - Resist A and B: 22 nm printing with rotated-dipole

Benchmarking conclusion (II)

- Imaging resolution meets 30 nm HP goal
 - 200-nm DOF @ 20% EL with Resist A
- LER/LWR remains primary challenge to meet needs for 32 nm HP pilot lines.
- Reasonable process latitude demonstrated for 40-nm contact holes
- 35 nm contact hole printing demonstrated
 - High dose requirements (55 mJ/cm²) indicate major effort needed to meet 32 nm HP pilot line needs

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