TOK Resist Development Status for EUVL

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Contents

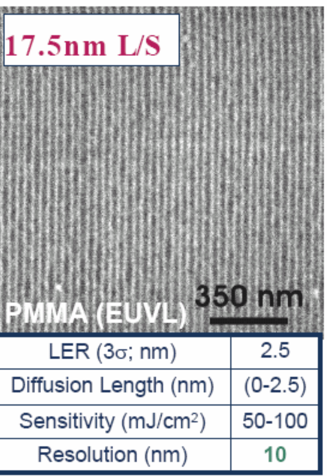
- Introduction
- EUV Resist Criteria
- Discussion
- Summary
- Acknowledgements

EUV Resist Specification

Contents	ITRS 2005 (Flash 2009)	ITRS 2005 (Flash 2012)	Current status	Countermeasure	TOK targets (Beta data in 2H,2008)
Resolution	45nm 1:1	32nm 1:1	35nm 1:1 (polymer resist)	Polymer aggregate Molecular size PAG quantum yeild Developer system …	32nm 1:1
Photo Speed	$5mJ/cm^2$ (115W)	ND	$18mJ/cm^2$ (polymer resist)	Molecular size Protecting group PAG quantum yeild Remaining solvent in resist film …	15mJ/cm2
				Remaining solvent in resist film …	
Etching	ND	ND	similar to Novolak	Carbon density Bulky structure …	Similar to Novolak
Resist Contrast	ND	ND	ND	PAG quantum yield Protecting group Molecular size …	TBD
Coating Uniformity	ND	ND	ND	Casting solvent …	< 2.0nm @ 300mm

New chemical design for EUV resist should be necessary.

Non-CAR vs. CAR



LER (3σ; nm)	2.5
Diffusion Length (nm)	(0-2.5)
Sensitivity (mJ/cm²)	50-100
Resolution (nm)	10

35nm L/S

CAR (EUVL)

LER (3σ; nm)	7.1
Diffusion Length (nm)	20.2
Sensitivity (mJ/cm²)	11
Resolution (nm)	35

Peter Leunissen, Sematech LER workshop, 2005

	Non-CAR	CAR
Resolution	☺	☹
Photo Speed	☹	☺
LER / LWR	☺	☹
Outgas	☹	☺

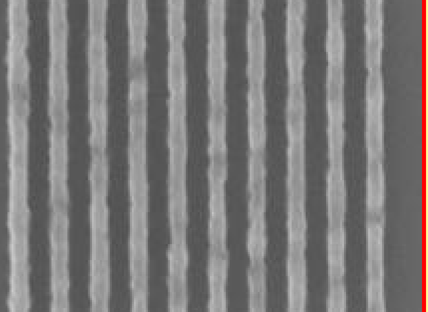
Is Non-CAR platform applicable to EUV resist ?

CAR Capability (Polymer Resist)

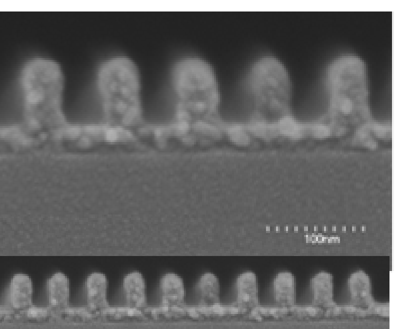
MET@Berkeley

Resist thickness: 80nm
Development: TMAH 2.38%

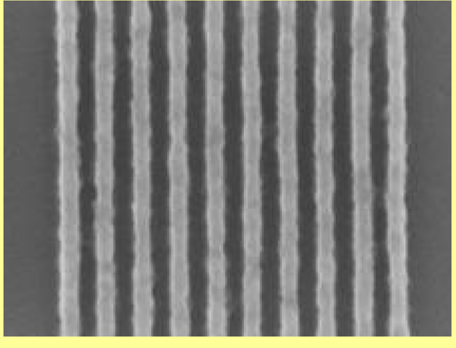
CD: 31nm
LWR 3σ: 4.3nm



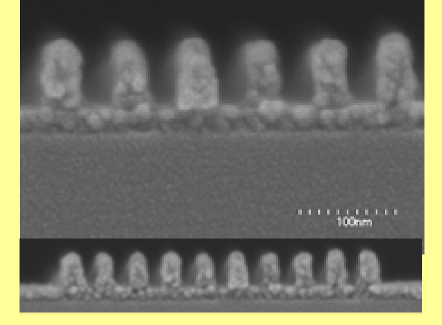
37.5 nm 1:1



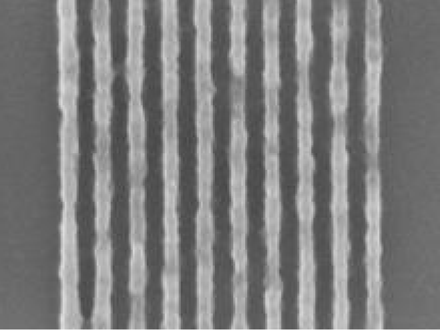
CD: 32.5nm
LWR 3σ: 4.3nm



35 nm 1:1

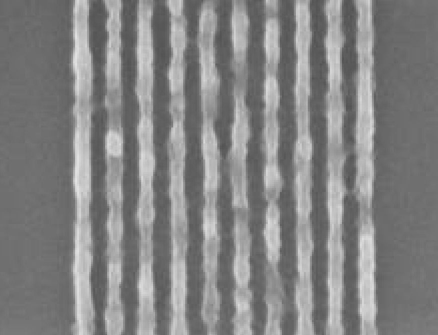


CD: 28nm
LWR 3σ: 5nm



32.5 nm 1:1

CD: 25nm
LWR 3σ: 9nm



30 nm 1:1

Dose : $18 mJ/cm^2$

Courtesy of collaboration company

Acid Generation Efficiency

1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5

Relative acid yield

0 10 20 30 40 50

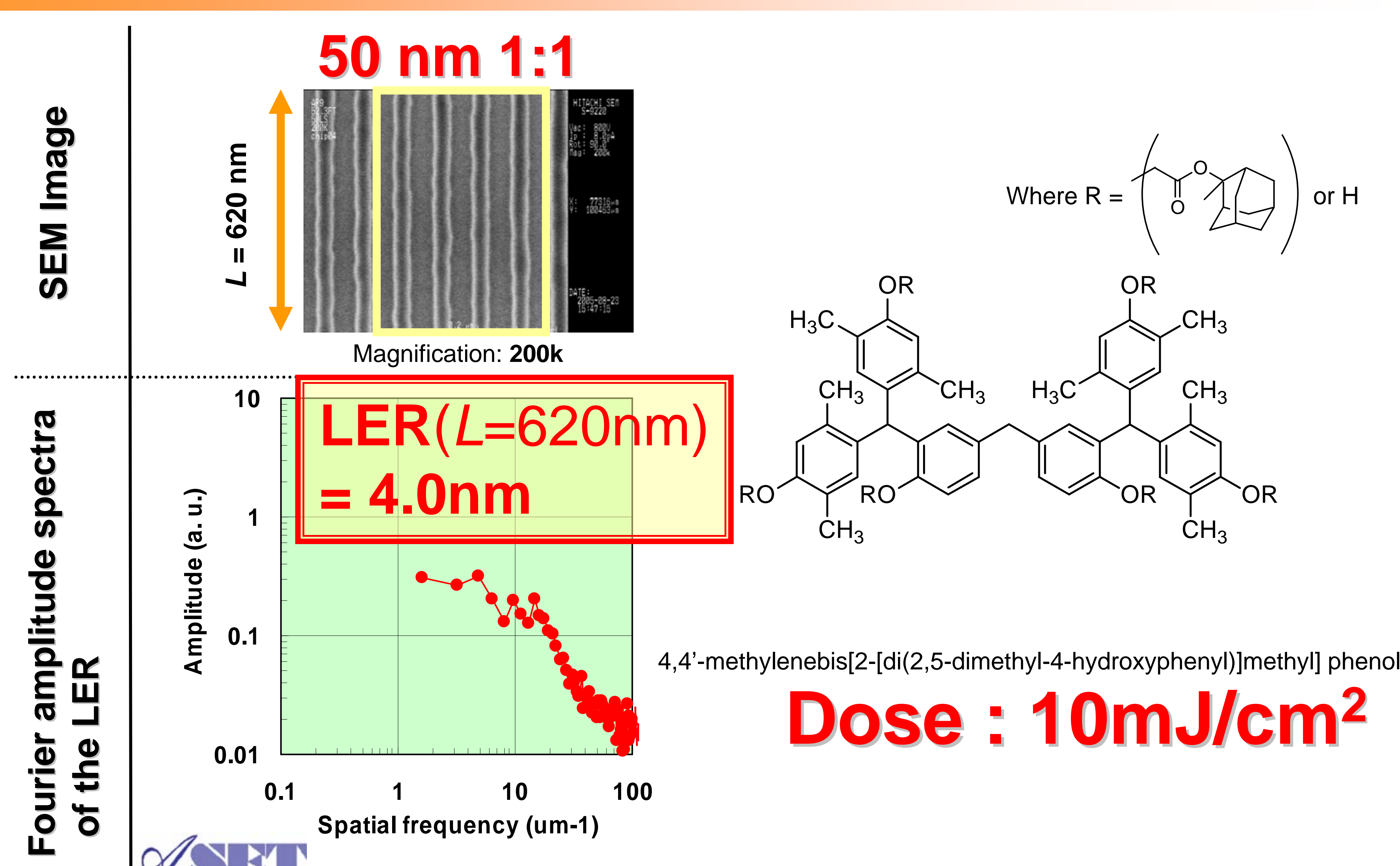
Protection ratio (%)

- tert-butyl
- adamanthoxyethyl
- naphthoxylethyl
- cyclohethoxyethyl
- ethoxyethyl
- tert-buthoxyethyl

S. Tagawa et al., Jpn. J. Appl. Phys. 43 (2004) L848 for PHS
S. Tagawa et al., J. Vac. Sci. Technol. B 22 (2004) 3522 for adamanthoxyethyl
S. Tagawa et al., Jpn. J. Appl. Phys. 44 (2005) 5836 for the other protecting groups

The protecting group and protecting ratio can contribute to acid quantum yield, and have significant effect on resolution capability and photo speed.

LER / LWR: Low Molecular Resist



H. Oizumi et al.: *MicroElectron. Eng.*, **84-87** (2006) in press.

Low Outgas

PAG structure study

PAG	Total pressure displacement (Pa)	Photo Speed@Eth
O_2S—CF_2 S+ -N CF_2 O_2S—CF_2	2.84 x 10^{-6}	1.1 mJ/cm^2
S+ $C_4F_9SO_3^-$	1.28 x 10^{-6}	3.8 mJ/cm^2
R S+ O_2S—CF_2 -N CF_2 O_2S—CF_2	3.05 x 10^{-6}	2.0 mJ/cm^2
R S+ $-SO_3F_9C_4$	ND	3.1 mJ/cm^2

H. Hada, et al., J. Photopolym. Sci. Technol. 18 (2005) 475

Protecting Group dependency

Protecting Group	Total pressure displacement (Pa)
	1 x $10^{\sim-9}$
tert-Bu	3 x 10^{-8}
EE	3 x 10^{-6}

H. Hada, et al., SPIE, 5374 (2004), 686

Achievement and Opened Issue

	Non-CAR	CAR (Polymer)	CAR (Low molecular)
Resolution	☺ ☺	☺	☺
Photo Speed	☹ ☹	☹	☹
LER / LWR	☺	☹	☺
Outgas	☹	☺	☺
Pattern Collapse	ND	ND	ND
PEB Sensitivity	ND	ND	ND
Delay Stability	ND	ND	ND
Etch	☹	☺ ☺	☺ ☺
Resist Contrast	☺	☺	☺
Coating Uniformity	ND	☺ ☺	ND

Summary

- We have been aggressively investigating major issues, such as resolution, photo speed, LER/LWR and outgas by accessing to multiple test sites.
- The polymer resist based on chemical amplified platform has achieved 1:1 line and space resolution beyond 35nm at 18mJ/cm^2 with 4.3nm line width roughness (3σ).
- Low molecular resist, which is an alternative approach to minimize line edge roughness, has shown 4.0nm line edge roughness at 100nm pitch size and 10mJ/cm^2 by utilizing specific protective group for optimum acid quantum yield.
- The relationship between outgas, PAG structure, and protective group under EUV irradiation have been shown.

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